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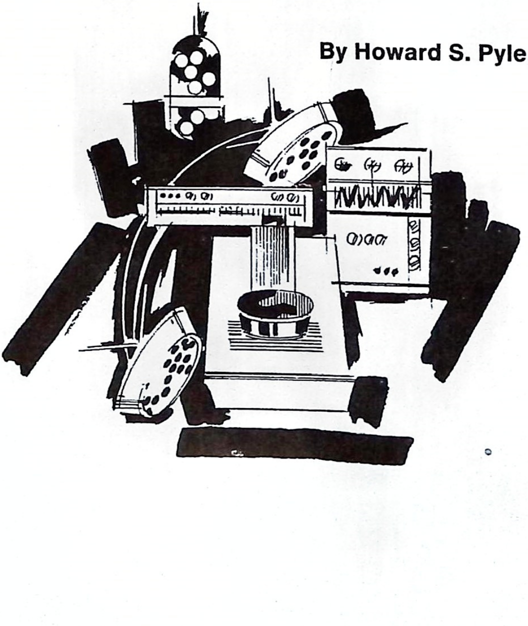
advanced and extra-class amateur license

HANDBOOK

A Comprehensive Study Guide to the FCC Examinations for the Advanced- & Extra-Class Amateur Radio Licenses

By Howard S. Pyle, W7OE



ADVANCED AND EXTRA CLASS AMATEUR LICENSE HANDBOOK

by Howard S. Pyle, W7OE

A Revision of
Extra-Class Amateur Radio License Handbook
by
Howard S. Pyle, W7OE

HOWARD W. SAMS & CO., INC.
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Preface

This book has been prepared to answer a demand from the holders of General, Conditional, and Technician classes of amateur radio licenses for a simple yet complete study guide for the higher grades of license. While no single publication can hope to cover all of the material in detail, in these pages much of the information you will need, together with suggestions for additional study and reference, is given. This book eliminates much tedious unorganized searching through various publications, and thus substantially reduces preparation time.

Amateurs holding the lower classes of license are understandably eager to upgrade their status by qualifying for either the Advanced or Extra class. The latter represents the highest recognition the Federal government can bestow on amateur radio operators and is, of course, the eventual goal of all eligible licensees. Many, however, after studying current literature for a few weeks, become discouraged. Lack of a more concise approach confined between two covers and presented in as simple a manner as consistent with the subject matter, has become a real problem. An attempt to rectify this situation has been made in the following pages.

A considerable amount of research, checking, and rechecking has necessarily been required to insure accuracy and authenticity. Every available source has been consulted and has contributed to the paragraphs which follow. In preparing this revised text it became increasingly evident that much of the basic material was common to both the Advanced and Extra class examination elements. This has permitted division of the subject matter into separate chapters for more convenient study reference. It is recommended that aspirants to either Advanced or Extra class licenses first study Chapters 2 through 11, followed by either Chapter 12 or Chapter 13, whichever is applicable to the examination they propose to take. Also, if their study time permits, prospective applicants for either class of license can continue their study by reading the chapter not directly applicable to the examination for which they are preparing. By so doing, the student will find that this additional effort contributes to broadening his overall knowledge of electronic subjects.

HOWARD S. PYLE
W7OE

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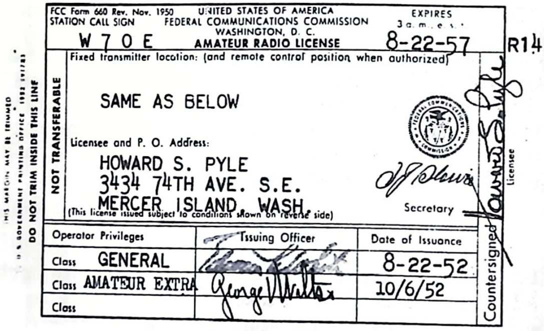
CHAPTER 1

Preliminary Considerations

1-1 The average individual, regardless of what line of endeavor he has chosen to pursue as a vocation or as a hobby, is anxious to progress to the greatest extent which his ability will permit. The junior officers of sea-going vessels for example, look forward to some day acquiring a Master's or Chief Engineer's ticket. The sports enthusiast constantly strives to win sufficient honors to place the crown of champion on his brow. Likewise, the radio amateur sets his sights on achieving the pinnacle of hamdom—the proud possession of an Extra-class license. Many prefer to attain this peak by first qualifying for the Advanced class. One reason for this is that the written examination is somewhat less exacting than that for the Extra class, although more comprehensive than that required for General. Additionally, the code test for the Advanced class is the same as for the General—13 words per minute—whereas that for the Extra class is at 20 wpm. An additional reason,but one which time soon takes care of, is the matter of eligibility which we will discuss in the following paragraph.

ELIGIBILITY

1-2 There are no particular eligibility requirements for the Advanced class license other than the applicant be an American citizen or National. This examination cannot, however, be taken by mail but must be taken at an FCC examining point or field office. In other words, an applicant who has never previously held an amateur license may present himself for this examination at any regularly established FCC examining point, should he feel qualified. The Extra class, on the other hand, requires that applicants must have held a Conditional, General, or Advanced amateur radio operator license for a period of two years prior to applying for the Extra class license. Such previous license must have been issued by the FCC and not one of its predecessor agencies, meaning that its date of issue must be subsequent to 1934, when FCC was established. Conditional class licensees are eligible *only* if they have confirmed their initial mail examination by repeating it in person before an authorized FCC engineer-examiner. The two year experience requirement in a lower grade is based on the assumption by Federal authorities that after two years of operation in lower class status, the applicant has increased his theoretical knowledge, his code speed, and his all-round operating ability as well. This is completely logical and the FCC stands ready to reward such increased proficiency by offering aspirants an opportunity to demonstrate their greater skills by passing the Extra-class examination. Successful applicants not only have their license cards endorsed for Extra-class operation (Fig. 1-1), but they may also be issued an impressively engraved certificate suitable for framing and display on the shack wall (Fig. 1-2). Holders of such a license



FCC Form 660 Rev. Nov. 1950
STATION CALL SIGN
W 7 O E

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D. C.
AMATEUR RADIO LICENSE

EXPIRES
8-22-57

R14

THIS MARGIN MAY BE TRIMMED
DO NOT TRIM INSIDE THIS LINE

NOT TRANSFERABLE

Fixed transmitter location: (and remote control position when authorized)
SAME AS BELOW

Licensee and P. O. Address:
HOWARD S. PYLE
3434 74TH AVE. S.E.
MERCER ISLAND, WASH.
(This license issued subject to conditions shown on reverse side)

Secretary

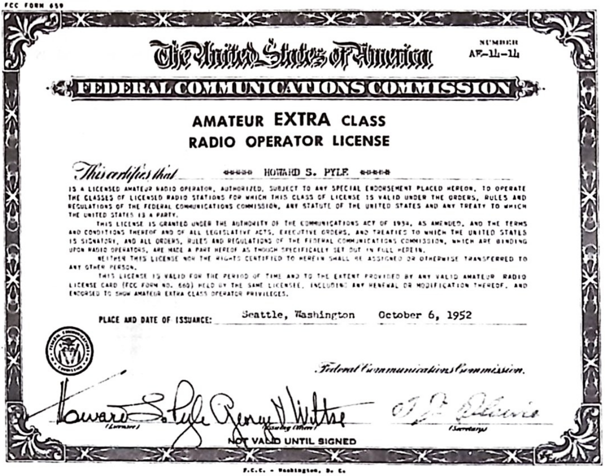
Licensee

Operator Privileges	Issuing Officer	Date of Issuance
Class GENERAL		8-22-52
Class AMATEUR EXTRA	George V Walter	10/6/52
Class		

Countersigned

Fig. 1-1. Wallet-size license card issued for all classes of license. Endorsement for Extra class is shown.

may, of course, operate their equipment in any mode and in any frequency band authorized for amateur operation.



FCC FORM 659

The United States of America

NUMBER
AE-14-14

FEDERAL COMMUNICATIONS COMMISSION

AMATEUR EXTRA CLASS
RADIO OPERATOR LICENSE

This certifies that ••••• HOWARD S. PYLE •••••

IS A LICENSED AMATEUR RADIO OPERATOR, AUTHORIZED, SUBJECT TO ANY SPECIAL ENDORSEMENT PLACED HEREON, TO OPERATE THE CLASSES OF LICENSED RADIO STATIONS FOR WHICH THIS CLASS OF LICENSE IS VALID UNDER THE ORDERS, RULES AND REGULATIONS OF THE FEDERAL COMMUNICATIONS COMMISSION, ANY STATUTE OF THE UNITED STATES AND ANY TREATY TO WHICH THE UNITED STATES IS A PARTY.

THIS LICENSE IS GRANTED UNDER THE AUTHORITY OF THE COMMUNICATIONS ACT OF 1934, AS AMENDED, AND THE TERMS AND CONDITIONS THEREOF AND OF ALL LEGISLATIVE ACTS, EXECUTIVE ORDERS, AND TREATIES TO WHICH THE UNITED STATES IS SIGNATORY, AND ALL ORDERS, RULES AND REGULATIONS OF THE FEDERAL COMMUNICATIONS COMMISSION, WHICH ARE BINDING UPON RADIO OPERATORS, ARE MADE A PART HEREOF AS THOUGH SPECIFICALLY SET OUT IN FULL HEREIN.

NEITHER THIS LICENSE NOR THE RIGHTS CERTIFIED TO HEREIN SHALL BE ASSIGNED OR OTHERWISE TRANSFERRED TO ANY OTHER PERSON.

THIS LICENSE IS VALID FOR THE PERIOD OF TIME AND TO THE EXTENT PROVIDED BY ANY VALID AMATEUR RADIO LICENSE CARD (FCC FORM NO. 660) HELD BY THE SAME LICENSEE, INCLUDING ANY RENEWAL OR MODIFICATION THEREOF, AND ENDORSED TO SHOW AMATEUR EXTRA CLASS OPERATOR PRIVILEGES.

PLACE AND DATE OF ISSUANCE: Seattle, Washington October 6, 1952

Federal Communications Commission.

Howard S. Pyle
(Licensee)

(Issuing Officer)

(Secretary)

NOT VALID UNTIL SIGNED

F.C.C. - Washington, D. C.

Fig. 1-2. Extra-class licensees receive this engraved certificate suitable for framing.

LICENSE PRIVILEGES

1-3 For many years, no special privileges were given holders of Advanced- or Extra-class licenses. Both of these were merely prestige licenses or status symbols. The General-class licensee was accorded identical use of all amateur bands and modes. Various amateur groups interested in providing an incentive for amateurs to upgrade their knowledge and skills urged that changes be made. In the fall of 1967, the FCC introduced the "incentive-licensing" program. Provisions were made for certain segments of various frequency bands to be available *only* to the Extra-Class licensee. To a lesser degree, similar provisions were set up for holders of the Advanced class of license. These arrangements provided for introduction in two steps; the first becoming effective November 22, 1968, the second, one year later as shown in Chart 1-1.

Chart 1-1. Incentive Licensing Privileges

Frequencies	Class of License Authorized	Effective Date
3500-3525 kc 3800-3825 kc 7000-7025 kc 14000-14025 kc 21000-21025 kc 21250-21275 kc	Amateur Extra only	November 22, 1968
3500-3550 kc 7000-7050 kc 14000-14050 kc 21000-21050 kc	Amateur Extra only	November 22, 1969
3825-3850 kc 7200-7225 kc 14200-14235 kc 21275-21300 kc 50-50.1 mc	Amateur Extra and Advanced	November 22, 1968
3825-3900 kc 7200-7250 kc 14200-14275 kc 21275-21350 kc 50-50.25 mc	Amateur Extra and Advanced	November 22, 1969

THE RADIOTELEGRAPH CODE

1-4 In addition to demonstrating his increased technical knowledge through written examination, the second requirement also specifies that the applicant for an Extra-class license must demonstrate his ability to send and receive in the characters of the International (Continental) radiotelegraph code at a speed of 20 words per minute (wpm). This is an increase of only 7 wpm over the speed requirement for the highest three of the lower grades of licenses. It can be assumed here that after two years of operation, of which a generous portion has been by *radiotelegraphy*, the code requirement should present no problem. The average General-, Conditional-, and Advanced-class licensee of two or more years experience habitually operates at speeds between 20 and 25 wpm. However, even to those of you who have devoted a fair proportion of your operating time to cw, it is still a wise precaution to check yourself or have another competent ham check you on your actual code speed; this is one part of the examination where it will not pay to kid yourself—you may *not* be quite as good as you think. Advanced class applicants holding a valid General class license will be exempt from the Advanced code test.

1-5 Hams who, after acquiring their General-, Conditional-, or Advanced-class license, have chosen to operate by radio*telephone* almost exclusively, may fall by the wayside here. While they demonstrated by examination that they were initially qualified at 13 wpm for one of these three grades of license, early abandonment of c-w operation in favor of phone has done nothing to increase their code ability. Some of the enthusiastic phone operators have, in fact, become "rusty" to the extent that it is probably doubtful that many of them could still make their 13-wpm speed. For people in this category there is but one answer; they must get in and *practice*, preferalby on-the-air, by contacting as many stations as possible and by devoting as much time as they can spare to c-w operation, augmented perhaps by some automatic code-transmission device. Fortunately, where they have slipped a bit in code speed due to neglect of this type of activity, it has been found that the "rust" rapidly wears off and they are back to their former 13 wpm in a few short weeks. For them, then, it is simply a continuation of c-w operation until they reach a solid-copy speed of 23 to 25 wpm. While 20 wpm is all that is required to pass the Extra-class code test, it is well, just as in applying for a lower grade of license, to appear for examination confident that you can meet the speed requirement with a few words a minute to spare. Regardless of your number of years of ham radio operation, you are bound to experience a slight nervousness during the examination period, and this will have a tendency to slow your speed to some extent.

EXAMINATION PROCEDURE

1-6 Having checked yourself or having been checked by others for assurance that you can meet the code speed requirement, if you feel that you have sufficient technical know-how to pass the written test, you are ready to apply for the examination. The procedure is exactly the same as for the General class; you appear at your nearest FCC examining point at a scheduled time and execute the formal application (Form 610).* Be prepared when you complete and turn in your application to hand the FCC representative four dollars, which represents the "filing fee."

---

* The Advanced- and Extra-class license examinations are never given by mail.

1-7 After passing the code test, both sending and receiving, you will receive questions additional to those of the General-class examination; these represent element 4(A) for the Advanced-class and element 4(B) for the Extra-class examination. The questions will be of the same general nature as those you were asked in your General or Conditional examination, but they will be much broader in scope. You will have to indicate, by drawing in accepted electronic symbols, schematics of a number of basic circuits. Some of the questions will ask you to identify certain common schematics.

1-8 You will be allowed all the time you feel necessary. Do not rush it by "guessing" at the probable answer to a seemingly tough one; take time to think it out thoroughly and logically. The same 74% required in other license examinations represents the passing grade, so you are allowed a little better than 25% leeway for questions missed. Just the same, strive for 100%, and come as close to it as you can—get 74% or better in the final anaysis and you "have it made." Arrange your day in advance so that you are prepared to spend the entire time right there in the FCC office until the "quitting whistle" blows. Do all that, *know* your subject, and you can leave with a pretty fair idea of whether you have been a successful candidate or whether you must be a "repeater" in thirty days.

THE "GRANDFATHER" LICENSE

1-9 Before closing this chapter it is fitting that the issuance of an Extra-class license *without* either code or written examination of any kind, to amateurs of long experience—the "Old Timers" or "OT's" of the ham fraternity—be discussed. Such an issue has been fittingly dubbed the "Grandfather license" in the amateur field. To be eligible for this "Gran'pappy paper" by merely filling out an application form, an applicant must qualify under the experience requirement—the length of time which the FCC regards as constituting sufficient amateur radio experience to warrant issue of the Extra-class license without examination. FCC Rules and Regulations, Part 97, Subpart C, paragraph 97.25, reads as follows:

> "An applicant for Amateur Extra Class operator license will be given credit for examination elements 1(C), 4(A),

> and 4(B), if he so requests and submits evidence of having held a valid amateur radio station or operator license issued by any agency of the United States Government *during or prior to April 1917,* and qualifies for or currently holds a valid amateur operator license of the General or Advanced Class."
>
> (The italics are the author's.)

From the preceding it will be seen that an applicant for an Extra-class license who is applying under the provisions of the "longevity" clause would, in 1968, have to submit evidence that he had been engaged in amateur radio activity for a minimum period of 51 years—no wonder hams have hung the tag of "Grandfather license" on this ticket.

1-10 The qualifying evidence required includes any radio amateur license dated in April 1917 or prior thereto or a certified copy of the same; a listing in an official U. S. Government callbook covering that period; or a rather wide selection of documents, papers, affidavits, letters, published material, and similar matter acceptable to FCC officials. Acceptance or rejection of the submitted evidence lies solely with FCC. If you are intending to apply for an Extra-class license under the "Grandfather" provision. it would be wise to first discuss the evidence you intend to submit to support your claim to amateur activity prior to May 1917 with your local area FCC field office. You can do this either in person or by mail, listing in detail just what your evidence will consist of. The FCC will advise you whether or not it is acceptable.

1-11 Suppose we discuss the subject a bit further with particular reference to that portion of the quote in paragraph 1-9 above which reads ". . . and qualifies for or currently holds a valid amateur operator license of the General or Advanced class." In addition to examination elements 1(C), 4(A), and 4(B), waiver of which is available under the "longevity" clause, you are also entitled to a waiver of *all* of the elements of the General-class examination *if* you hold a valid General- or Advanced-class license. If you do *not* hold such a license at the present time although you have at one time held either a General-, Conditional-, or Advanced-class license for two years, you will still be required to take the examination elements applicable to the General class, even though you qualify for waiver of elements 1(C), 4(A), and 4(B) under the

"Grandfather" provision.* In other words, *if* you can produce acceptable evidence of having engaged in bona fide operation of an amateur radio station prior to May 1917, *if* you currently hold a valid General- or Advanced-class license, and *if* you have held such license for a period of at least two years, you can be issued an Extra-class license without examination of any kind by merely filing your application, paying your fee, and submitting your evidence either by mail or in person. On the other hand, if you otherwise qualify for the "Grandfather" issue but do not currently hold a valid General- or Advanced-class license, you will be required to pass the General-class examination.

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* See Appendix A for explanation of the above elements.

CHAPTER 2

Building Up Your Code Speed

2-1 Regardless of how much c-w operating experience you have, it seems to be only human to feel that, while you are pretty sure of your technical knowledge, you just *might* find the code test to be more of a barrier than you thought. Maybe you have a code proficiency certificate from the ARRL issued in recognition of your qualifying at a speed of perhaps 25 words a minute. Possibly a 30- or maybe even a 35-wpm stamp has been later affixed, yet for some psychological reason there is a tendency to think, "I *hope* I can make the code test." In a way this attitude may be good; you will check and recheck yourself many times before you decide to take the bit in your teeth and appear for examination. Checking yourself or being checked by others will probably increase your confidence as you find that you are copying pretty solid at 25 wpm or better. You concentrate more on the individual letters when you are doing such checking and do not just grab the gist of a word while mentally filling in a letter or two here and there which QRM, QRN, or ITV knocked out in your on-the-air contacts. In the examination you must get *every* letter in sequence in a group of 100 characters and put them down legibly on paper. You have five chances; get as many of these as you can. You have one big advantage in the examination which is sadly lacking in your ham operation; you will have no fading, no QRN or QRM, and no weak signals to fight. You will get the entire transmission at the steady even speed of 20 wpm with all characters perfectly formed and spaced by an automatic transmitting machine which sends in a pleasing audio tone at a comfortable level.

2-2 This chapter is more concerned, however, with those who have devoted practically their entire operating time to radio telephone operation. As was mentioned previously, in most cases this results in a "film of rust" forming over the code-ability base. This class of operator is going to have to use considerable "rust remover" to get the scales off his code speed and step it up to a good 20 wpm or preferably 23, 24, or 25 wpm to allow the safety factor. How is he going to do it? Study and practice are the only recourse. Learning the code, even for the Novice class, is usually found to be quite a chore; increasing speed for the higher-grade examinations may be not quite so tough although some seem to think it is. Actually, once the code is learned and reasonable ability is acquired (even at the Novice speed) *that* bridge is behind you; you already *know* the characters of the code; all you must do is learn to recognize them faster.

HOW TO DO IT

2-3 Probably one of the best ways by which to increase your code speed is through actual on-the-air operation. If you can consistently copy actual radio signals through static, interference, and possibly room noise at any rate of speed at all, you can be pretty sure that you can do two or three words a minute *better* when copying in a quiet room from a pleasing note produced by an audio oscillator. That is a point in your favor. There is, however, a catch to gaining speed through actual c-w operation. You will not gain very much, if any, if you pick only stations to work who are sending at a speed which allows you to make solid copy. Pick an operator who is moving right along at a speed which offers you a challenge; one who puts you on your toes to stay with him. You have a natural reluctance to have to ask for repeats so you are going to extend yourself to keep pace. This system will gain speed for you in jig time if you consistently follow this practice.

There is a chance for you to go wrong here also; rather than ask for a repeat of certain portions of his transmissions, you may slip into a tendency to grab what you can and make a stab by guessing where you really should ask for a fill-in. This is understandable; it is the same reluctance mentioned above. You do not want him to think you are a "lid," so you take a chance and hope that you are right. In most instances no harm is done when engaged in more or less casual conversation. You would not guess at what you *think* is the proper word to cover one you missed in a formal message, however; to do so is a sign of a poor operator and contrary to amateur ethics.

Try to avoid the guesswork practice; either you get what the other fellow sends or you ask him to repeat it. Do not feel at all reticent about this; the other fellow does not know whether or not his signals were momentarily covered by QRM, maybe a burst of static, or just by dropping your pipe in your lap. He does not necessarily think of you as a poor operator, particularly if your fist is relatively good.

2-4 Naturally, to engage in two-way c-w operation as a means of increasing your code ability calls for both a transmitter and a receiver; as an active amateur you already have both. Suppose though that you are temporarily without a transmitter; the thing broke down and you have not had time to fix it yet, or maybe you have sold it and have not found a new one to suit you. At any rate, if you are limited to just a receiver, you are not at all out of the running for code practice under on-the-air conditions. The ARRL runs regular and frequent code-practice sessions the year round through the League's station W1AW. Write them for their latest code-practice schedules, and copy, copy, *copy*. Again though, do not make the mistake of picking a speed which you can copy solid. The practice transmissions are sent at various speeds which are gradually stepped up at definite intervals during each practice session. Pick a speed just *beyond* your solid-copy ability; and get all of it you can. When solid copy becomes easy at that speed, take the next higher level and stay with that one until you master it. You are sure to boost your receiving ability in this manner, and it will not take many practice sessions to do it.

2-5 The ARRL station is not the only one sending code practice on regular schedules. Many radio clubs throughout the country have inaugurated such practice sessions as a regular part of their activities. Some even use automatic tape transmission, as is done at W1AW; others rely on hand sending by a competent operator with a good fist. The ARRL will furnish you a list of such stations in your own area. Some individual amateurs have also voluntarily taken on the task of providing on-the-air code practice. Again, the ARRL can name a number of these for you, and your local radio club will also have such information.

So, with a completely operative station you can engage in two-way c-w communication and "learn by doing"; limited to a receiver only, you can "learn by copying." Next, the possibilities for the unfortunate ham who currently has *neither* a transmitter nor a receiver should be considered.

2-6 The note on which the preceding paragraph ended represents a rather sad state of affairs. What enthusiastic ham operator would be caught short with *no* equipment? A ham, however, could hold a perfectly valid operator and station license but no gear, and there could be many reasons for this. Possibly he has sold his station preparatory to moving to a distant point, perhaps temporary financial difficulty may have forced the sale of his equipment, or serious family illness or a death may have changed the pattern of his living considerably, necessitating temporary abandonment of his ham-radio activity and storage of his gear. A dozen reasons could be named to account for a "no-equipment" station. He wants to come back though, and until he can, an excellent opportunity is presented to him to pursue his study with the aim of returning to the air with a brand-new Extra-class license. Lacking the actual physical equipment for on-the-air code practice, he has two choices; perhaps he can borrow a communications receiver from some friendly ham who has an "extra," or he can resort to one of the automatic code-transmitting devices.

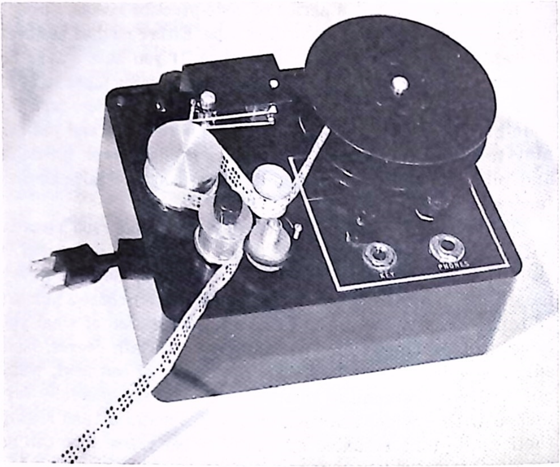
MECHANICAL CODE-PRACTICE EQUIPMENT

2-7 All of us are familiar to some extent with the various types of code-practice equipment nationally advertised in the ham magazines and in mail-order catalogs and stocked by many of the amateur-radio supply stores. For the purpose of building up receiving speed, the familiar key and buzzer or key and audio-oscillator combinations are of little value. They will serve you only as a means to improve your *sending* if you feel the need to brush up on proper character formation at 20 wpm.

For *receiving* practice you must necessarily have something that will simulate the sending of another operator by mechanical means or present a series of code-practice lessons through phonograph records or recording tape. Either method has been proven satisfactory in actual practice. If you have a tape recorder with playback, you can purchase suitable tapes to fit it. You can have some friendly ham, using a recorder, tape the code-practice lessons on the air from his receiver, and you can play them back at home. If you have a phonograph turntable and pickup arm, the LP records offered by several manufacturers can serve you well.

These two methods, recorded tape or phonograph records, will cost you less than other types of practice equipment if you have the gear with which to use them. Both, however, have one minor drawback in that unless you purchase a number of tapes or records, you are limited to repetition of what you have already copied and probably, to a certain degree, have subconsciously memorized. The devices described next, while not entirely overcoming this minor defect, are generally furnished with a wider selection of practice material, and having their audio tone actuated by simple paper tapes, they can be modified to provide an even wider variety of practice material. This is easily done by merely snipping the tapes into several shorter lengths and pasting them together at random after having used them as originally supplied. By so doing, the material on the tape becomes a mixture which breaks the continuity of what you have previously copied. Using rubber cement with which to patch the tape will allow it to be readily peeled apart when it has served its purpose, rearranged in another combination, or restored to its original condition.

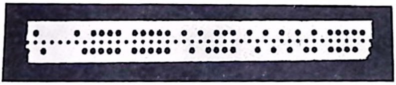
2-8 The phonograph records, recorded tapes, or the paper tape machines must lend themselves to adjustment for various speeds. The phonograph records and recorded tape, of course, can easily be controlled by varying the speed of their driving motors. The paper-tape machines are also provided with a speed-control adjustment either by varying the motor speed or through a conical or other form of friction drive; either method is satisfactory. The physical makeup of these paper-tape machines is basically the same even though the individual models vary in details. Some have a built-in audio oscillator and loudspeaker; the oscillator may be either transistorized or of the tube variety. Others are supplied without an oscillator and speaker on the assumption that the purchaser already has this equipment; this type, of course, is less costly.



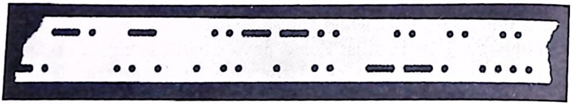
Courtesy Automatic Telegraph Keyer Corp.

Fig. 2-1. The *Mini-Keyer* is furnished with or without a built-in tone source and speaker.

The *MINI-KEYER* shown in Fig. 2-1 uses standard Wheatstone perforated tape (Fig. 2-2) and is available from Automatic Telegraph Keyer Corporation, 275 Madison Avenue, New York 10016. When the machine is purchased without a built-in tone source and speaker, it sells for $39.50; with these items. $49.50.



(A) Standard Wheatstone tape used in the ATKO "Mini-Keyer."

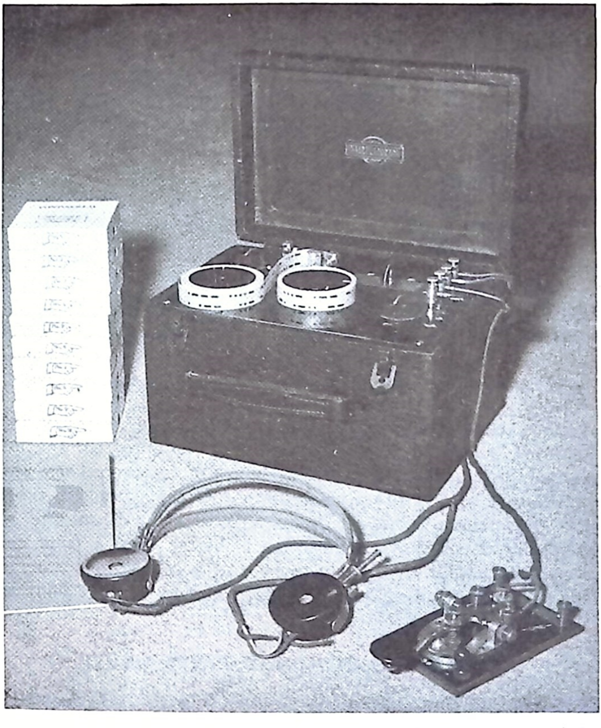


(B) Perforated paper tape used in "Instructograph" and Gardiner keyers.

Fig. 2-2. Perforated tapes used in automatic code transmitters.

Some machines can be rented as well as purchased from the manufacturer. The rental cost is nominal, usually being about $5.00 monthly. You will be required to pay the postage both ways on rental equipment.

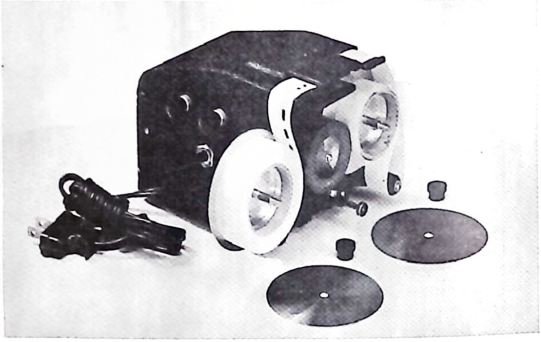
2-9 Most of the oscillator-equipped machines are provided with terminals to which a telegraph key can be connected, thus permitting sending practice through the built-in audio system. The purchase price of machines such as these described varies from about $30 to around $50; they all have good resale value



Courtesy Instructograph Co.

Fig. 2-3. The *Instructograph* automatically produces audible code from perforated paper tape.

when you are through with them. Some hams elect to keep them and in turn rent them out to other hams desiring code practice. In this way they recover the cost of the machine in a little while plus a bit of profit if they wish to continue renting their machine to others. Two other pieces of equipment of this type offered by national manufacturers of good repute are shown in Figs. 2-3 and 2-4; what you choose is, of course, up to you.



Courtesy Gardiner Co.

Fig. 2-4. Another type of code-practice device that employs paper tape.

2-10 As a final word on this subject, the necessity for an orderly schedule of practice must be emphasized. Do not attempt to cram in two or three hours of copying at one session and then drop it for a week or more; stay with it in *frequent short sessions.* Half an hour with a 5- or 10-minute break midway through your practice is better than a solid one or two hours. Get in two or more half-hour sessions daily if at all possible; you will be surprised at how rapidly your speed will increase.

CHAPTER 3

Power Supplies

3-1 Now that the preliminaries and the various means open to you to increase your code speed have been discussed, it is time to consider the *technical* angles involved in progressing toward the ultimate in ham achievement. It is probably desirable to start with the obvious bottom rung of the ladder, which is power-supply sources for transmitting equipment. Having been through at least two years of ham operation as a licensed General- or Advanced-class amateur, you may think that this subject is "old hat" and that you can take it in stride without burning any midnight oil. This may be so, since you have learned a lot in these past years, but it is also entirely possible that you have become a bit vague on some of the finer points of power generation with which you have not been too closely concerned. If you have been designing and building equipment, you probably have a much better store of knowledge than the ham who, after getting his station on the air, is more interested in operation than in construction. He is in about the same class as the fellow who has spent almost all of his time on phone, neglecting his c-w operation. Regardless of which category you fall into, a bit of a brush-up will certainly do you no harm.

FIXED-STATION POWER SUPPLIES

3-2 In any discussion of power supplies for energizing radio-frequency generating equipment such as transmitters or a power source for receivers, only two factors are of concern: the initial *input* power and the resultant *output* power. For convenience, these will be referred to as the primary (input) source and the secondary (output) source. At first thought the latter term may seem a bit ambiguous, but when you think of the *output* of a power supply as actually becoming the *input* to the radio-frequency circuits, it thereby serves as the *source* of supply to the latter.

Primary Power Sources

3-3 In radio applications there are but two primary sources: alternating current (ac) or direct current (dc). The former is used almost exclusively in the United States as a source of supply for fixed-station equipment. In the isolated instances where *direct* current must serve as the primary source, it must either electrically drive a d-c motor which in turn mechanically drives an a-c alternator, or it must initially be of a voltage equal to the greatest voltage demanded by the radio equipment. Various *lower* voltages as may be required throughout the r-f circuits such as for tube filaments, relay operation, and similar low-voltage devices are then secured through dropping resistors or voltage dividers. If, however, a d-c motor drives an a-c alternator, conventional transformation of the a-c supply to higher and lower voltages, as required, becomes possible.

3-4 Prior to the 1920's, when vacuum-tube transmission was in its early stages, a motor-generator combination was highly popular as a source of high-voltage dc for low- and medium-power amateur transmitting equipment. These were offered by a number of manufacturers as *motor-generator sets*. They consisted of an a-c motor driving a high-voltage d-c generator. Both units were mounted on a cast iron base, and their shafts were coupled together. Such devices, particularly in the higher voltage-output class, were relatively expensive. The most popular ham sizes were those producing from 500 to 1000 volts of direct current. Higher voltage outputs were available, but their greater cost generally restricted their use to hams who could afford the expensive tubes, such as the 204-A, that required such higher voltages.

Voltage Transformation

3-5 The ac/dc motor-generator set had a relatively short life from the standpoint of popularity. Transformer manufacturers were quick to recognize the market which radio amateurs presented for the sale of thousands of small transformers which could be priced far below the cost of motor-generator sets. Scores of such manufacturers began producing thousands of filament, plate, and combination transformers at a reasonable cost to the consumer. The swing then, on the part of the ham fraternity at large, was to the generation of both high and low a-c voltages through the use of transformers. These transformers, by proper proportioning of multiple secondary windings placed in inductive relation to a primary winding fed from a commercial a-c source, could produce just about any combination of voltages which were in demand.

3-6 Some hams elected to make their own transformers, but this practice, unless the experimental bug had taken a *big* bite, soon became rare. Building up an iron core lamination by lamination and winding thousands of turns of fine wire on one leg for the high-voltage secondary output, which called for excellent insulation, proved to be a chore of some magnitude. For a relatively few dollars a manufactured product of greater efficiency, smaller physical size, and a more pleasing appearance was readily available.

3-7 Transformers solved the voltage problem. The standardization of tube filament voltages, plate voltages, and the voltages required for a-c relays simplified transformer design. Manufacturers needed only to provide several low-voltage secondary windings and one winding of a higher voltage than the primary commercial a-c source. Generally, windings producing 2 volts, 5 volts, and later 6.3 volts took care of the low-voltage requirements. The high-voltage windings were designed to produce voltages anywhere from about 250 to 2000 volts. These became available in "standard" sizes of 250, 350, 500, 600, 750 volts, and even higher voltages to meet user demands. Designers of factory-built transformers increased the efficiency of their products by taking into consideration certain losses which are inherent in a device of this kind—calculations which are a bit difficult for the average amateur builder. The two major losses which occur in transformation are known as *eddy currents* and *hysteresis losses.**

3-8 In view of the great popularity of the *full-wave* rectifier system (discussed in a later paragraph), center tapping of the *high-voltage* transformer winding is almost universally practiced by transformer manufacturers. Center taps are also often provided on one or more of the low-voltage windings, permitting greater versatility in circuit design. Whether in connection with either plate or filament windings, the center tap represents the *electrical* center of the winding, and the voltage produced between the center tap and either end of the winding is one half that of the winding measured from end to end. Identical voltage readings in both halves of the secondary, however, are somewhat theoretical; the actual voltages will be close enough to each other to be quite adequate for average use. To obtain absolute balance in the two readings introduces manufacturing difficulties which would add to the cost of the product; therefore such complete accuracy is generally confined to transformers built for laboratory applications.

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* See questions 1 and 2, paragraph 3-32 at the end of this chapter for definitions.

RECTIFICATION

3-9 As most of you know, radio-frequency current can be generated by applying a-c voltage values to the plate of a tube equivalent to the d-c voltage requirements of the tube. It is, of course, illegal to do so for radiocommunication purposes, although in the early stages of vacuum-tube transmission by amateurs, "raw ac" was often used on the plates. Obviously, even in the pioneer days, such a source of plate potential was entirely impractical for the ham radiotelephone. The pure direct-current carrier, so vital to carry the modulated signal, was completely lacking, and the hum level was of such magnitude in a receiver that nothing intelligible could be distinguished. Some indication of a throaty gargle was about as close to determining that voice modulation was being attempted as one could get. On the other hand, c-w transmission *could* be accomplished since the key permitted the starting and stopping of the "gargle" in the character formations of the code. The note was naturally far from pleasing, since it was modulated by the 60-cycle a-c component. It *did* serve for communication after a fashion, but the top speed limitation was only about 15 to 20 words per minute at best, even between a couple of crack operators.

Electron-Tube Rectifiers

3-10 Some improvement soon came along with the adoption of what was termed *self-rectification,* wherein two radio-frequency tubes arranged with proper circuitry served a dual purpose by acting as full-wave rectifiers as well as r-f output tubes. The resultant note then became a frequency of 120 cycles, making interpretation of code characters somewhat easier. At best, however, this still sounded like a stick being rapidly scraped along a picket fence, as did the 60-cycle note (the latter "stick" only being moved half as fast, however). This raw-ac business was a long way from what the hams, and soon the Federal officials, considered good radiocommunication. A few of the commercial operating companies had a fair measure of success with this method, however, particularly on shipboard, where a 500-cycle a-c supply was generally available. This made for a much more pleasing note of the *interrupted continuous-wave type,* known as *ICW*. The interruptions, of course, were those of the 500-cycle alternator.

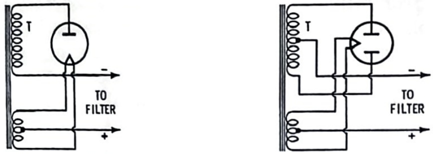
3-11 It was not long before raw ac was legislated out, and shortly after, ICW for amateur use also went by the board. Hams then became limited to using a motor-generator set to generate their high d-c voltage or devising a means of creating a pure d-c high voltage to radiate a continuous wave. A few farsighted individuals who apparently read the "handwriting on the wall" had been experimenting with various rectifiers for changing the high-voltage ac from the transformer to at least a semblance of direct current. One of the early forms these rectifiers took was the electrolytic or *slop-jar* type. This type was so termed because it was made up of a dozen or so fruit jars, or similar jars, partially filled with various solutions in which lead and aluminum conducting elements were suspended. By feeding this rather questionable device (which often, when overloaded, would boil over on the floor and smell to high heaven) with the raw ac from the transformer, some fairly smooth dc was realized from the output side. Mechanical devices, the forerunners of present-day vibrators used with mobile radio equipment, were tried in crude forms, but with little success, and they were soon abandoned. A number of methods, such as the rotary synchronous rectifier and many others, were tried, but they were abandoned practically overnight.

3-12 In the interim, vacuum-tube manufacturers had not exactly been dozing; the familiar mercury-arc rectifier tube and the smaller *Tungar* bulbs, then widely used for battery-charging and similar purposes, evidently sparked some heavy thinking. In conventional form the mercury-arc and *Tungar* tubes were designed to handle much more current and far less voltage than radio transmitter circuits called for. Some experimentation along these lines was accomplished with a bit of promise, and then the highly exhausted type-80 full-wave rectifier and its companion half-wave rectifier, the type-81, were developed. That did it; hams everywhere cherished these little "Aladdin's lamps," and manufacturers were hard pressed to keep pace with the initial demand. Now they had it; a device that did just what it was expected to do, allow one half of each a-c cycle applied to it to pass from filament to plate, thus creating rapid spurts of voltage in only *one* direction—*direct* current at last. The type-81 tube, because it was the half-wave type and had but one anode (plate) and a filament, put out a somewhat jerky dc by reason of the rise and decay of one half of the a-c cycle. But it *was* dc, although of a pulsating type, and by using *two* of the type-81 tubes, one passing *one* half of the cycle and the other the *opposite* half alternately, much smoother dc was possible. If the ham's wallet could stand the extra cost of the additional tube and socket, this was well and good; the type-80 tube, on the other hand, being fitted with *two* anodes and a filament, could by itself serve the purpose of two type-81 tubes, one of its plates rectifying half of the cycle and the other plate taking care of the opposite half. Obviously the type-80 became the more popular of the two although the type-81 in pairs had a rather wide acceptance due to its ability to handle more current than the type-80, thus permitting somewhat greater transmitter power. Both tubes, however, due to their low voltage and current limitations, were adaptable to only relatively low-power transmitters. The ham initially limited himself to powers in the 25- to 50-watt power-input range in his early vacuum-tube transmission experiments, so the small rectifier tubes served very well in carrying these light loads. Transmitting tubes for the r-f circuits were then manufactured only in the low-power class for the amateur market. One or a pair of the justly famous 7.5-watt type-210 transmitting tubes (often overloaded) comprised the early vacuum-tube ham rig.

Larger tubes of 50- and even 250-watt power-input capacities were being manufactured for commercial interests, but these were not immediately released to the amateur field. When they did become available to this market, it was at a rather prohibitive cost. For example, the 50-watt type-203 tubes sold to the ham for a net price of $30 each; their filaments could burn out just as quickly and easily as a $5 or $10 tube. Some hams, serving in radio capacities in World War I, had managed to filch a few of the Army/Navy type VT-2 tubes which were rated at 5 watts but were capable of withstanding considerably more power input, and quite a few were in use. Regardless of the choice of r-f output tubes, *all* types were required to be supplied with a d-c voltage "as pure as consistent with the state of the art," to quote from the then existent Federal regulations. This simply meant, except in a few remote instances, that *rectified* ac must first be produced by the power supply; either the type-80 or -81 vacuum-tube rectifier would provide this but it still was not pure *enough.*

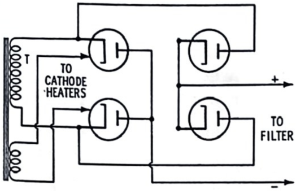
The Bridge Rectifier

3-13 The circuit of Fig. 3-1C represents a configuration of tubes and circuitry known as a *bridge* rectifier. Through its use it is possible to obtain approximately *twice* the average output voltage from the rectifier that can be had from the conventional half- or full-wave circuits of Figs. 3-1A and 3-1B, assuming use of the same transformer. The well-known phrase, "you can't get something for nothing," is applicable here, however. If you double the voltage output by using a bridge rectifier, you will realize only *half* of the current that would be available using the circuits of Figs. 3-1A or 3-1B. It stands to reason then that if the transmitter load demand is to be maintained at the level normally used with the more conventional half- or full-wave rectifiers, the transformer secondary should be rated to handle *twice* the current that would be drawn by the circuits of Figs. 3-1A and B or the transformer will suffer a 100% overload—while it lasts. It then becomes a monetary question if the transformer must be replaced. Add to this the cost of the additional tubes, sockets, and filament transformers required for bridging, and it becomes somewhat of a toss-up except perhaps in connection with the higher-powered transmitters with rather heavy voltage demands. While Fig. 3-1C shows four half-wave rectifier tubes, a single full-wave tube could replace two of the half-wave types, if the high-voltage secondary of the transformer is center tapped, as most are. This, however, saves only the relatively minor

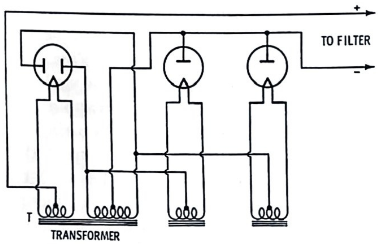


(A) Half-wave vacuum tube.

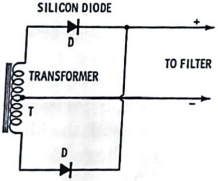
(B) Full-wave vacuum tube.



(C) Vacuum-tube bridge (4-tube).



(D) Vacuum-tube bridge (3-tube).



(E) Full-wave silicon diode.

KEY TO SYMBOLS

D -- SILICON DIODE
T -- TRANSFORMER

Fig. 3-1. Basic rectifier circuits.

cost of one tube and one socket. Fig. 3-1D illustrates such a circuit.

Mercury-Vapor Rectifiers

3-14 Somewhere along the line, probably with thinking still in terms of the mercury-arc battery-charging tubes, it was found that a small pool of mercury placed internally at the base of the stem in the tube greatly reduced the internal resistance and consequent voltage drop within the tube; such voltage drop was reduced to an average value of only 15 volts, and this varied very little under load. The vapor from the mercury pool after the pool had become heated by the filament or "heater" gave off a cloud which accounted for the better conductivity in the interior of the tube envelope. Users were cautioned to allow a minimum "warmup" period of at least 30 seconds (preferably a bit more) before attempting to draw current through the tube. With the lowered internal resistance it was obvious that some increase in output voltage resulted in allowing a few more watts input to be applied to the transmitter circuits. Mercury-vapor tubes were made available in voltage ratings up to 2000 and current ratings as high as 1250 ma, which more than took care of all ham requirements within the legal transmitter input power limit of 1 kilowatt. Circuits used with mercury-vapor tubes are identical with those of the gaseous-type rectifiers, but they sometimes require minor additions. For example, mercury tubes often create a slight but annoying "hash" in receivers, dictating filtering at the plate connection of each tube. In aggravated cases, it may be necessary to also shield the tube and perhaps add filters in the power-supply line to eliminate this type of oscillation.

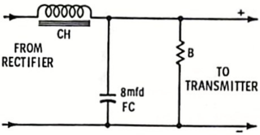
Mineral-Diode Rectifiers

3-15 While high-vacuum and mercury-vapor tubes are the most widely used rectifiers, in recent years the introduction of silicon and germanium for rectifying purposes has provided a simple and convenient means for producing rectified ac, and these are rapidly gaining favor. Silicon is the more highly favored since it permits a much wider range of voltage- and current-handling capability. In proper designed power supplies, it can handle voltages in the neighborhood of up to 2000 volts inverse-peak-voltage rating at 500 ma; even greater capacity is possible, but it would exceed legal limitations for the amateur. Their compactness and lack of necessity for a filament supply add to their desirability. Silicon diodes can be substituted for any of the half-wave or full-wave vacuum-tube rectifiers shown in Figs. 3-1A, B, C, and D; Fig. 3-1E illustrates this. For greater voltage handling capacity than is provided by a single diode, two or more may be connected in series The germanium diode is rather limited in voltage handling characteristics, although some can handle up to 1 ampere of current.

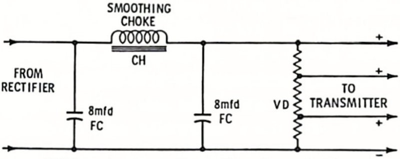
3-16 Federal regulations call for the purest possible d-c voltage. Simply rectifying the ac, while satisfactory from the standpoint of equipment operation for continuous-wave telegraphy, does *not* constitute a purity "consistent with the state of the art." Neither does it serve satisfactorily for *radiophone* operation. Refinements are necessary to reduce (preferably eliminate) what little a-c component is still being superimposed on the pulsating dc from the rectifier tubes. This, then, brings up another very important element of the power supply—the filter system.

FILTERING THE PULSATING DC

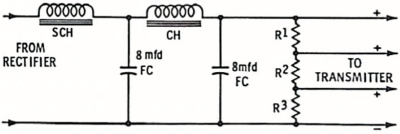
3-17 As mentioned in the preceding paragraph, rectification by itself does not constitute the generation of sufficiently pure dc. The filter is also referred to as a *system,* and that is exactly what it is. Electrically, a "system" is a combination of components so arranged in circuitry that a desired result is produced. In a filter system the end result to be achieved is to "smooth out" the ac remaining in the output of the rectifier. A conventional filter system (Figs. 3-2A, B, and C) is composed of one or more iron-core choke coils and one or more paper, mica, or electrolytic capacitors. In addition, a *bleeder* resistor, often serving as a *voltage divider* as well, is highly desirable, although it does nothing directly to assist the smoothing operation of the choke(s) or capacitor(s). The bleeder is just what its name implies; it serves to "bleed off" a small portion of the d-c current issuing from the filter components ahead of it by placing a very light load on the filtered output. This serves first to stabilize the d-c output to some extent by not requiring the keying of the transmitter to take the full output of the filter in a sudden jump from zero to maximum. Such keying by reason of the bleeding action of the resistor merely *increases* the current drawn from the filter with each manipulation of the key, or the push-to-talk switch in radiotelephone operation. In addition, the bleeder resistor serves to quickly dissipate the residual charge remaining in the filter capacitor(s) after keying has ceased.



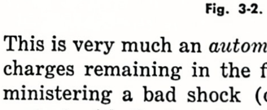
(A) Choke-input filter with bleeder.



(B) Capacitor-input filter with voltage divider.



(C) Two-section filter using separate resistor string.



(D) Filter for MG set or dynamotor.

KEY TO SYMBOLS

B--BLEEDER RESISTOR
CH--SMOOTHING CHOKE
SCH--SWINGING CHOKE
FC--FILTER CAPACITOR
VD--VOLTAGE DIVIDER
R1, R2, R3--FIXED RESISTOR STRING (VOLTAGE TAPS TAKEN OFF AT SPLICE POINTS BETWEEN RESISTORS)

Fig. 3-2. Basic filter circuits.

This is very much an *automatic* safety device, because residual charges remaining in the filter capacitors are capable of administering a bad shock (occasionally fatal) if you come in contact with the hot side of the equipment circuitry.

3-18 When acting as a voltage divider, the bleeder resistor is a type fitted with adjustable sliders which can be moved along the resistance wire in a bared path, permitting any desired voltages *lower* than the maximum which the filter delivers to be taken off for transmitter stages with lower voltage demands (Fig. 3-2B). Once adjusted, the sliders are seldom touched unless modifications of the transmitter circuits dictate different values of d-c voltage. For a transmitter i which such modifications are not contemplated, a string o fixed resistors of proper values to provide the desired voltage can be substituted for the adjustable type of voltage divide (Fig. 3-2C). The resistor string is made up with all resistor in series and the various voltages taken off at the junctio points between them. As the two ends of the string are (lik the adjustable voltage divider arrangement) connected directly across the output of the filter system, the string serve as a bleeder as well.

Filter Chokes

3-19 It was stated previously that a filter system is compose of one or more choke coils and one or more capacitors; suppose we first discuss the choke coils. Such a choke is, in effec "half a transformer," comprising, as it does, but one windin on an iron core. The makeup of the core is similar to that o a transformer; that is, a hollow rectangle built up of sheet metal laminations. Many turns of fine wire are wound ove one leg of the core, which might be any of the outer legs, o in some cases a "center leg" (also of laminated metal) spanning the gap of the hollow rectangle. The size of the wire i dependent on the amount of current in milliamperes which i will be required to carry. The physical makeup of choke coil is of no particular concern; you should concentrate on thei *function* in power-supply circuits.

3-20 Choke coils are of two types: the *smoothing* choke an the *swinging* choke. Both types should be of such design tha their inductance (in henrys) is of a value such as to produc the desired choking action; such value is referred to as th *critical* value. This value is determined from the formula:

$$L_{crit} = \frac{E}{I}$$

where,

L_{crit} equals the critical inductance value of the choke in henrys,
E equals the voltage output of the power supply,
I equals the value of current in ma drawn from the filter system.

Unless a choke of either type is so designed to present at least the critical value of inductance, the choke will have a tendency to act more as a capacitor than a choke. If a choke, rather than a capacitor, is used as the input to a filter system and the choke has at least the critical value of inductance, the maximum rated output current may be drawn from the rectifier, assuming, of course, that the milliampere capacity of the choke is such as to handle this amount of current. The voltage at the output end of the choke, however, will be somewhat less (approximately .9) than that from the rectifier at the input end of the choke. This is dependent on the amount of resistance which the choke winding presents to the voltage flow from the rectifier. While this voltage drop is of relatively small value, it is taken into consideration in properly designed transmitter circuits. Normally a smoothing choke is used directly in series with the output voltage of the rectifier in what are known as choke-input filters. The smoothing action presented by such a choke, having an inductance of at least the critical value in henrys, tends to smooth out the pulsations or ripple in the voltage issuing from the rectifier. In most cases, a single choke of this type followed by a suitable capacitor (Fig. 3-2A) offers sufficient smoothing effect to provide a d-c output from the filter which will meet the legal requirements for "pure" dc.

Ordinarily, hum-free voice transmission will result through the use of such a combination of choke and capacitor, which is termed a *single-section* filter. Should an audible hum component still remain however, a second section can be added to further reduce any remaining hum to an inaudible level. The addition of a swinging choke and a capacitor ahead of the single-section filter comprises the second section of a filter system and changes the identity of the system to a *two-section* filter rather than the single-section type using one choke and one capacitor (Fig. 3-2C).

Filter Capacitors

3-21 In describing the filter system of either one or two sections, a capacitor used in connection with such systems was mentioned in the preceding paragraph. For the type of filter wherein the choke coil appears immediately at the output of the rectifier identifying it as a choke-input filter, the capacitor is placed directly across the positive and negative supply *after* the d-c voltage has passed through the choke. The addition of such a capacitor assists the smoothing action of the choke by tending to bypass to ground (negative high voltage) any a-c ripple remaining in the d-c voltage, while allowing the dc to pass through its normal path to the transmitter circuit.

3-22 Placing an additional capacitor across the *output* of the rectifier at the *input* end of the choke constitutes what is termed a *capacitor-input* filter (Fig. 3-2B). With this type of filter system, voltage regulation is somewhat poorer than with a choke-input filter, but with adequately rated filter components throughout, it is not of sufficient concern to be disturbing. The chief advantage to be gained by using a capacitor rather than a choke input to the filter system is that a somewhat higher d-c output is available to the transmitter circuits. Capacitor-input filters are ordinarily used with only low- or medium-power transmitters where the resulting higher voltage (about 10% average) allows a few more watts input to the transmitter.

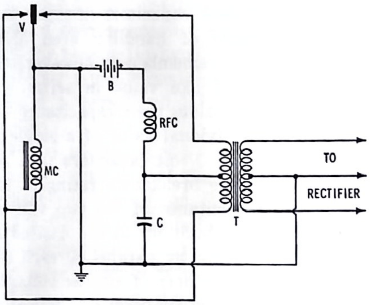
3-23 When choosing filter capacitors, be sure to select ones with a low reactance at audio frequencies. A popular value which generally proves adequate is 8 mfd, although somewhat higher values are sometimes used to provide better regulation in the power supply. The accepted minimum of 8 mfd can be provided in a single unit, but if only lower values are available, they can be paralleled to provide the equivalent. Two 4-mfd capacitors, for example, in such a parallel arrangement will equal the desired 8 mfd. Regardless of the mfd rating of such capacitors used alone or in parallel, it is important that their breakdown voltage be such as to avoid the possibility of such failure in service. Capacitors should be chosen with a voltage rating of at least 25% more than the maximum voltage to which they will be subjected in the power-supply application. For use in a power supply providing a maximum voltage of 500, for example, capacitors should be rated to withstand at least 625 to 650 volts; 750 to 800 volts breakdown rating is even more desirable, particularly for the first capacitor in a capacitor-input filter. Such capacitors are readily available in these approximate ratings on the open market and in the popular electrolytic type. This type is preferable by reason of its small physical size; it is almost universally used in transmitters of the low- and medium-power class.

Proper combinations of such capacitors in series and parallel arrangements are capable of handling even higher-power equipment. It should be remembered, however, that while placing two capacitors of like value in series will double their voltage breakdown value, their capacitance will be reduced to one half the individual value of a single capacitor. To illustrate, two 8-mfd 600-volt capacitors in a series connection will have a voltage breakdown rating of 1200 volts, but the total overall capacitance of the two will be 4 mfd. This arrangement can be built up to the desired 8 mfd at 1200 volts breakdown rating by paralleling each of the two 8-mfd capacitors with two others of similar voltage and rating, although this is not often the most economical answer.

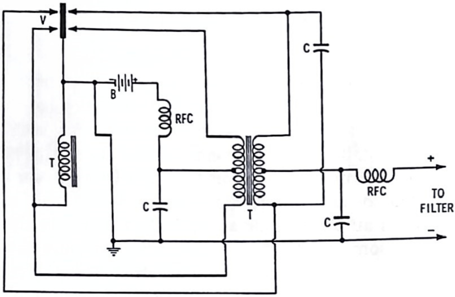
MOBILE POWER SUPPLIES

3-24 With the great popularity of mobile amateur operation from surface vehicles such as automobiles, aircraft, small boats, or larger vessels, this chapter would not be complete without reference to power-supply sources for such radio operation (Fig. 3-3). Since no commercial alternating current is available to a mobile unit, some other *primary* power source must be provided. Ordinarily, this is the 6- or 12-volt storage battery in an automobile, or an equivalent source in airplanes or boats. In some relatively few instances, amateurs have provided commercially available a-c alternators. These alternators are usually belt-driven by the primary motive power plant of the mobile unit. These, of course, present no departure from the conventional a-c actuated power supplies which have already been examined; starting with the power transformer, they are identical throughout.

3-26 Where dependence is placed on a d-c source, such as a storage battery, the transformer and rectifier of the conventional a-c power supply must be ignored, except in the case of relatively low-power mobile equipment which makes use of a vibrator fed from a storage battery to activate an a-c transformer. Continuing from such a transformer, the balance of the power supply is the same as for the fixed station; the transformer output feeds to a vacuum-tube or silicon rectifier system and thence through a conventional filter arrangement to the radio equipment. Vibrators are commercially available



(A) Plain vibrator.

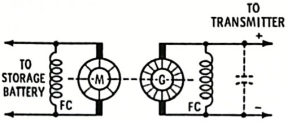


(B) Synchronous vibrator.

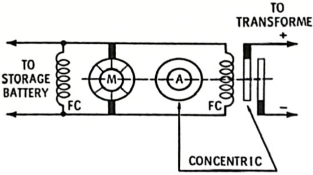
Fig. 3-3. Basic mobile

with companion transformers in which an a-c voltage is induced in the transformer secondary by the pulsing dc created by the vibrating reed. Obtainable also are vibrators of the synchronous type which are fitted with an additional pair of contacts which, by proper circuitry, serve to rectify the secondary output to pulsating dc, which may then be fed directly into a conventional filter system.

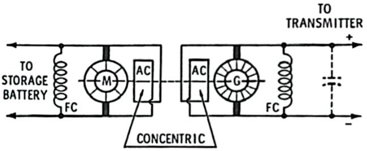
3-27 In paragraphs 3-3 and 3-4 dc as a primary-supply source was mentioned. Such a source must either drive a motor which in turn mechanically drives an a-c alternator or a high voltage d-c generator, or the initial d-c supply must be of a voltage



(C) Motor-generator set.



(D) Motor-alternator set.



(E) Dynamotor.

KEY TO SYMBOLS

A--ALTERNATOR
B--STORAGE BATTERY
C--BYPASS CAPACITORS
FC--FIELD WINDINGS
G--GENERATOR
M--MOTOR
RFC--RADIO-FREQUENCY CHOKE
T--TRANSFORMER
V--VIBRATOR
AC--ARMATURE COIL
MC--VIBRATOR MAGNET COIL

power supplies.

equal to the maximum demand of the radio equipment it is intended to power. The now relatively rare *commercial* d-c source infrequently available to a fixed radio station is generally in the neighborhood of 110 volts. Obviously this is hardly sufficient to supply the plate circuits of even the lowest-powered radio equipment; either the d-c motor, a-c alternator, or d-c motor-generator sets are the only practical alternatives for the fixed station. A somewhat parallel problem is presented in powering mobile radio equipment. Except where the vibrator type of mobile power supply as discussed in paragraph 3-26 is chosen, a choice between a motor-alternator or a motor-generator set must be made. While not the most common, d-c motor and a-c alternator combinations are used to some extent for mobile work. These are in more general use in police and other emergency vehicles than by amateurs; some will also be found in aviation and marine applications. It is again obvious that with such a combination, alternating current equivalent to that available to the fixed radio station is provided, and the conventional transformer, rectifier, and filter arrangement takes care of the high-voltage requirements of the radio equipment.

3-28 Where motor-generator sets (a d-c motor powered from a storage battery driving a high-voltage d-c generator) are used in mobile radio installations, they are most generally of the type known as a *dynamotor* rather than the two-unit arrangement of a separate motor/generator coupled mechanically. The dynamotor is a more compact device, which has been a large factor in popularizing its use in mobile applications where space is often at a premium. Another important consideration is that a large proportion of amateur mobile operation is accomplished using military surplus equipment, and almost without exception, dynamotors serve as the high-voltage d-c source. Actually, the dynamotor, in its electrical characteristics, is identical with an MG set. It receives low-voltage dc from a storage battery and produces high voltage dc at its output terminals. Physically, such a unit combines the motor *and* the generator in one housing, with an armature fitted with *two* windings, one serving the motor portion and the other the generator. These windings are connected to two separate commutators, one at either end of the shaft. One commutator receives the dc from the storage battery; the other provides the high-voltage d-c output of the generator winding.

3-29 In addition to serving as the primary source for a vibrator, motor-alternator, or MG set for mobile operation, the storage battery is also called on to serve as a source of supply voltage for tube filaments and relay operation. It is evident then that with the current demand placed on the storage battery by the combined load (the motor of the MG or motor-alternator set or the vibrator, and that required for filament and relay operation) a storage battery must be kept in tip-top condition at all times if it is to also serve in its original capacity as a starting-motor supply source as well as serving the various lights and the ignition system of the mobile unit.

This calls for frequent charging, and the maintenance of the specific gravity and the level of the electrolyte in each cell at the proper values. Frequent or prolonged use of the radio equipment often so exhausts the battery that it is no longer capable of starting an engine or supplying lights of normal brilliance without frequent periods of extensive charging. Many hams resort to a *second* battery in their mobile unit so arranged to feed *only* the radio-equipment demand but capable of being switched to the charging generator to replenish the lost capacity of the battery. Similar arrangements using two batteries are often used as well by paralleling an additional battery with that of the regular battery of the vehicle. By so doing, the current capacity of *both* batteries is available for all electrical demands, including the radio system, and both batteries automatically charge in parallel from the conventional charging circuit of the mobile unit. Other hams have solved the problem of "one battery for all needs" by boosting the charging current supplied from the charging generator. This is not a recommended method, however, since it sometimes breaks down, or burns out, electrical components and frequently some of the wiring that is not designed to handle excessive current.

3-30 When an MG set supplies high-voltage dc, or an equivalent dynamotor serves in this capacity, no rectification of the d-c output is involved. Since its output is dc, it can be wired directly into the filter system (Fig. 3-2D). Some commercially available MG sets and most military surplus dynamotors have a built-in filter system on the output side or supplied as a separately housed companion unit. Ordinarily these are satisfactory without external filtering. Where such filters are not supplied with the machine, or the accompanying filter is inadequate to serve the receiver portion and perhaps the audio section of the radio equipment, additional filtering is required, but this imposes no particular problem. The usual filter in such machines is merely a capacitor of 2- to 4-mfd capacitance across the generator output with a few r-f chokes introduced into the line in series. Placing additional capacitance across the d-c output from the generator is generally sufficient to smooth the output to a satisfactory value. For machines with no filter supplied, similar treatment, using 4- to 8-mfd capacitors and an r-f choke or two, will ordinarily handle the problem in connection with a *good* generator. By "good," we mean a machine which has a generous number of commutator segments (within mechanical limitations) ; when there are more segments, the ripple introduced into the d-c output is less.

3-31 The preceding pages should give you a sufficient understanding of the various components of a power supply for supplying radio equipment used in both fixed and mobile applications. A "thumb-nail" historical background discussion having to do with power supplies was purposely introduced in the earlier portion of this chapter. This will serve to not only refresh the memory of the old timers of amateur radio, but will allow a more intelligent application of such power-producing sources by those hams who have had little previous experience other than the 2 years as a General- or Advanced-class licensee.

Before proceeding to the following chapter, a series of questions based on the preceding paragraphs to test your knowledge are offered. While these questions are, of course, not the actual ones which you will be asked in the license examination, they are similar in character, and you should study them thoroughly along with the answers.

3-32 POWER-SUPPLY QUESTIONS AND ANSWERS

1. What is meant by the term "eddy current" as applied to a power transformer and how can such currents be minimized?

Ans. Eddy current represents the small current induced in the iron core of a transformer when the primary coil encircling the core is energized. Such current causes heating, which represents wasted power. These currents can be reduced by using thin iron laminations in the construction of the core, and insulating such laminations from each other by coating each with an insulating varnish or shellac.

2. What is meant by "hysteresis loss"?

Ans. Hysteresis loss is the resistance of the iron core to any change in its magnetic state, which is caused by the rapid reversal of the ac applied to the primary winding of the transformer. Because a small amount of such ac is diverted to overcome this core resistance, it produces nothing and is therefore a loss.

3. Define the difference between a motor-generator set and a motor alternator.

Ans. A motor-generator combination consists of a d-c motor driving a d-c generator; a motor-alternator set uses a d-c motor to drive an a-c alternator.

4. What is the purpose of a "rectifier system" in a power supply using a transformer?

Ans. A transformer produces alternating current at various voltage values from its secondary winding. This must be rectified or changed to direct current before it can be used for radio purposes.

5. What two types of vacuum-tube rectifiers are most commonly used for radio power supplies?

Ans. The high-vacuum type and the mercury-vapor type.

6. How does a mercury-vapor rectifier tube differ from a high-vacuum type?

Ans. A small pool of mercury is introduced internally at the base of the tube stem. When heated through proximity to the filament or heater, the mercury tends to give off a vapor which fills the tube envelope, thereby lowering the internal resistance of the tube. This permits somewhat greater voltage output from the rectifier. A high-vacuum type of tube contains no such foreign element and is exhausted to a high vacuum in manufacture.

7. What precaution should be observed in energizing a rectifier system using mercury-vapor tubes?

Ans. The tube filaments should be allowed to "warm up" for a period of at least 30 seconds to permit vaporizing of the mercury before connecting the tubes to their normal load.

8. Name one *disadvantage* of the mercury-vapor tube.

Ans. It has a tendency to create an electrical "hash" which is often discernible as an annoying noise in radio receivers. This can be substantially reduced by insertion of a 50- to 100-ohm resistor in the plate lead of each tube. Aggravated cases may require metallic shielding of the transformer and tube and the insertion of radio-frequency chokes in the power-supply line.

9. What advantage does a "bridge rectifier" offer?

Ans. By using a bridge rectifier it is possible to practically double the voltage output (.9 rms actually) but in so doing only half the normal current consumption can be utilized unless the transformer secondary is capable of supplying normal current without exceeding its rated capacity.

10. Can mineral diodes replace vacuum or mercury-vapor tubes in accepted conventional rectifier circuits?

Ans. Yes; no basic circuit changes are required other than elimination of the filament supply. Caution should be taken to maintain proper polarity in initial connection.

11. The mineral diode rectifier has what advantages over those of the vacuum-tube or mercury-vapor types?

Ans. The diodes are physically much smaller and they require no filament supply source.

12. What is the purpose of a filter system?

Ans. A filter system smooths out the pulsations in the d-c voltage from the rectifier, which are caused by the a-c component remaining in the output after rectification. This action serves to "purify" the d-c output from the filter system.

13. What is a "bleeder resistor"? Define its purpose.

Ans. A bleeder resistor is generally a winding of resistance wire around a ceramic core, although a carbon resistor of similar value may be used in low-power applications. Connected across the output of a filter system it serves to "bleed off" a small amount of current, thereby placing a light load on the power supply system. This prevents a sudden surge of full power followed by decay to complete zero when controlled by the manipulation of a telegraph key or a switch. The bleeder also serves as a safety device by providing almost instant discharge of the filter capacitors when power is removed from the filter system.

14. Describe how a bleeder resistor may also serve as a "voltage divider" to make a number of different voltage values available from the filter system.

Ans. Rather than a straight resistance winding with only end terminations, divider resistors are made with a narrow lengthwise strip of their vitreous enamel coating removed to expose the bare wire. Several loop-around metal sliders are supplied which may be adjusted along the length of the winding and secured at points which provide the desired voltages. The full length of the resistor continues to serve as a bleeder as well.

15. How may a string of carbon resistors serve as a voltage divider as well as a bleeder?

Ans. By calculating the value of the individual resistors required to produce the desired voltages at several tie points between the resistors.

16. How is the overall resistance value of a bleeder or voltage divider calculated?

Ans. By assuming the current drawn by the bleeder resistor to be approximately 10% of the total transmitter load current and applying Ohm's law.

17. What is the physical makeup of a filter choke coil? Name two types.

Ans. A filter choke uses a core made up of thin laminated iron sheets similar to that of a transformer. Around one leg is wound a predetermined amount of relatively fine wire to obtain a desired inductance value. A "pig-tail" wire lead is brought out from either end of this winding to permit connection in the filter system circuitry. Both *smoothing* and *swinging* chokes are used in power-supply filters.

18. Describe a filter capacitor and its use.

Ans. An electrolytic capacitor for filter circuits is generally housed in a metal or bristol-board cylinder approximating the diameter of a flashlight battery cell and about twice as long. Wire pigtails are brought out for circuit connection and are plainly identified as to "positive" and "negative" terminations. Internally, sheets of metallic foil (usually aluminum) are stacked with a conducting chemical compound between them. By application of direct current to the capacitor a very thin insulating film is caused to form on one set of plates by electrochemical action. Such capacitors are used in filter circuits to assist in smoothing the pulses from the rectified dc supplying the filter system by bypassing to ground whatever a-c component appears in the rectified dc.

19. Where are such capacitors electrically connected in a filter system?

Ans. In a choke-input filter system, the capacitor is connected from the positive to the negative lead of the filter output, after the voltage has passed through the choke coil. In a capacitor-input filter, the capacitor is connected across the rectified d-c line *before* it passes through the choke.

Generally, a similar capacitor is also used *behind* the choke as in the first example.

20. What is the generally accepted primary power source for mobile radio equipment?

Ans. Either the existing storage battery of the mobile unit or a similar battery installed primarily for radio operation.

21. What additional equipment is required for use with a storage-battery primary-voltage supply source for mobile equipment?

Ans. A vibrator, a motor-generator set, a motor alternator, or a dynamotor; a rectifying and filter system are also required.

22. What other means of rectification of the output of a vibrator supply can be used in place of vacuum tubes or mineral diodes?

Ans. A *synchronous* type of vibrator provided with additional contacts which, through proper circuitry, provide a rectifying action.

23. Can filtering of the d-c supply in mobile radio applications be accomplished with conventional filter systems or must special components be used?

Ans. Standard filter systems applicable to either a d-c supply from a transformer and rectifiers, a vibrator source, or a motor-generator or dynamotor may be used.

24. How does a dynamotor differ from a motor-generator set?

Ans. Physically, a dynamotor has its motor or driving unit and its "dynamo" or generator encased in the same housing. They share the same revolving armature. Electrically, the armature is fitted with two windings, one for the motor and one for the generator. The driving source (generally a storage battery) feeds one commutator at one end of the armature; the opposite end is equipped with an additional commutator from which the high voltage of the generator output is drawn. The motor-generator set on the contrary is composed of two *separate* units, individually housed and mechanically coupled together. Each unit has its own armature and commutator.

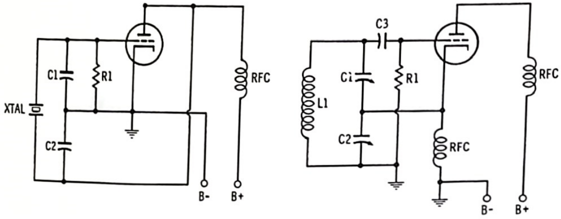
CHAPTER 4

Radio-Frequency Oscillators

4-1 Logically the next step beyond the power-supply system is the radio-frequency oscillator whereby the generation of r-f energy takes place. In vacuum-tube oscillators there is a choice of a number of circuits; basically they are identical in that they all oscillate at a predetermined frequency. Such oscillation frequency is determined either by a quartz (or sometimes other mineral) crystal plate or through properly proportioned coils. These coils are adjustable in inductance (as in band-switching transmitters) together with a continuously variable capacitor. The crystal plate type wherein the quartz wafer controls the oscillation frequency is, of course, limited to the generation of oscillations only at the frequency for which the crystal has been ground. This is known as the *fundamental* frequency; additional frequencies, referred to as *harmonics*, at twice, three times, four times, and even higher multiples of the fundamental frequency are simultaneously generated. While such harmonics have an increasingly lower output as the frequency is increased, advantage is often taken of such generation, particularly in the vhf and uhf ranges. Through the use of frequency *multiplying* stages, radiation from the antenna system can be made to fall at any selected harmonic frequency of the fundamental.

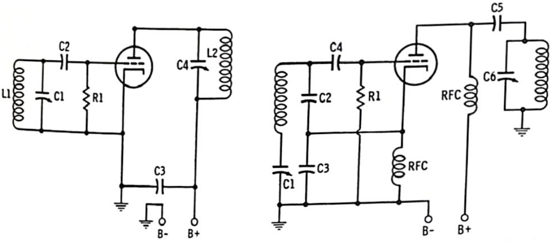
BASIC OSCILLATOR CIRCUITS

4-2 In Fig. 4-1 the most commonly used circuits for the production of r-f oscillation are shown. There are a number of other circuits in practical but not common amateur use, most having been devised for various special applications. Those of the crystal-controlled type sometimes employ minerals other than quartz, particularly in connection with high-precision



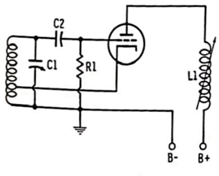
(A) Pierce crystal oscillator.

(B) Tunable Colpitts oscillator.



(C) Tuned-grid tuned-plate circuit.

(D) Series-tuned Colpitts with shunt feed.

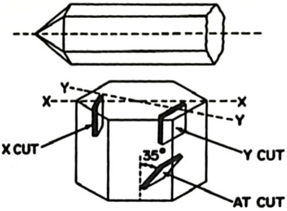


(E) Series-fed Hartley.

Fig. 4-1. Basic tube oscillator circuits.

laboratory devices. Because quartz crystals are, however, almost universally used in amateur applications, these will be the only ones discussed here.

4-3 A perfect natural crystal has a hexagonal-shaped cross section as shown in Fig. 4-2. Also illustrated in Fig. 4-2 are



(A) The shape of the quartz in its natural form.

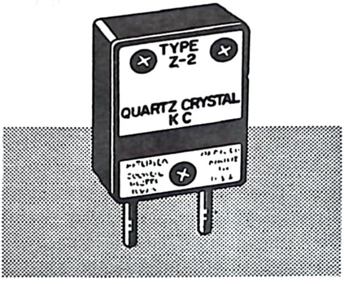
(B) The angles at which quartz crystals are cut.

Fig. 4-2. The quartz crystal.

the various angles at which quartz crystals are cut from the natural form, as required for r-f generation purposes. For general amateur application the "X" and "Y" cuts and to some degree the "AT" cut are those most frequently encountered. Such crystals are almost invariably mounted in a hollow rectangular enclosure designed to protect them from dust and other foreign matter and to provide, by means of small contact plates under slight pressure, a method of circuit connection. Such holders are generally fitted with two prongs similar to those of a vacuum tube for convenience in plugging in and out of a circuit. For readers not familiar with the physical makeup of a crystal holder, Figs. 4-3 and 4-4 show the details of crystal mounts.

4-4 All crystals possess what is known as *piezoelectric* properties. This simply means that they are capable of vibration (not discernible to the naked eye, however) at the frequency for which they have been ground when they are connected to a source of electrical potential. Conversely, application of electrical energy which creates vibration of the crystal causes it,

Fig. 4-3. A typical crystal holder.



through its mechanical motion, to *generate* alternating-current electricity at the crystal resonant frequency. It is this relatively small output current which is utilized in radio circuits; it is built up to the desired values by passing it through one or more amplifying stages.

4-5 Probably the most simple crystal oscillator is that of the Pierce type (Fig. 4-1A) which has no provision for manual tuning adjustments. Basically, this is a Colpitts circuit wherein a crystal replaces the inductance of the tuned circuit as well as the variable feature of the capacitors. Through its vibratory action the crystal places a negative charge on the grid of the oscillator tube, which results in reduction of the plate current, causing the grid to become more negative and thus further reducing the plate current until the cycle reverses itself. This process is continuously repeated as long as electrical energy is applied to the crystal. The result is the production of an a-c voltage at the frequency for which the crystal has been ground.

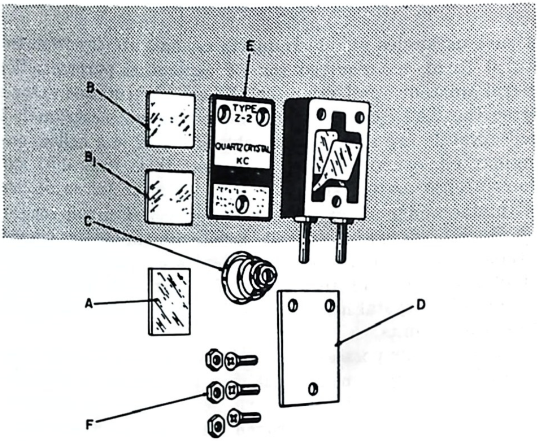


Fig. 4-4. Internal construction of a crystal holder.

4-6 The basic Colpitts circuit may be restored by substituting a tuned circuit in place of the crystal, as shown in Fig. 4-1B. The use of two variable capacitors which act, in effect, as a "voltage divider," immediately identifies the circuit as a Colpitts as distinguished from the Hartley circuit. The Hartley circuit (Fig. 4-1C) uses *one* such capacitor, and the inductance is tapped. The location of the tap on the coil and the value of C3 in the circuit determine the amount of energizing or *feedback* voltage fed back to the tuned circuit from the plate of the tube to initiate and sustain oscillation.

4-7 Another type of vacuum-tube oscillator which at one time enjoyed high popularity in amateur radio circles, but which in late years has fallen somewhat into disuse, is the *tuned-plate tuned-grid* type. This is shown schematically in Fig. 4-1C. It is just what the title suggests; both the plate *and* the grid circuits of the tube are tuned to the same frequency. The small interelectrode capacitance of the tube provides the feedback which causes the circuit to oscillate.

VARIABLE-FREQUENCY OSCILLATORS

4-8 Any circuit, such as those shown in Fig. 4-1, that will produce radio-frequency oscillations which can be tuned to any desired frequency over a wide range, are considered as *variable-frequency oscillators*, or *vfo's* as they are popularly termed. A complete transmitter powered from such an oscillator and feeding into various amplifying stages is often termed a *master-oscillator power-amplifier* transmitter (MOPA). This term is, however, used more in connection with equipment for commercial radio use than in the amateur radio field, although it is, of course, applicable to either. Casual amateur terminology generally refers to a vfo as the oscillation generator if a crystal is not used. It is taken for granted that the vfo is usually followed by conventional amplifier stages. Very seldom is a master-oscillator, or vfo, used by itself as a transmitter, although *any* r-f oscillator, including the crystal type, is perfectly capable of delivering excitation to an antenna system at relatively low powers. While a variety of oscillator circuits are used both in home-built equipment and in commercially built vfo's, kits, and complete transmitters so equipped, the Colpitts circuit with some minor variation or modification seems to be the most popular type.

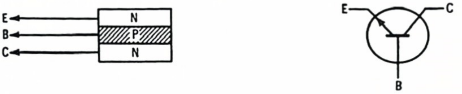
4-9 The terms *series* and *shunt* feed are frequently referred to in any discussion of radio transmitter circuits, including oscillators. Fig. 4-1D shows an example of shunt feed inasmuch as the plate voltage feeds only the plate. This circuit is known as the series-tuned Colpitts, or Clapp, oscillator. Series feed is illustrated in Fig. 4-1E; the high voltage reaches the plate after passing through the inductance; they are thus in "series" with each other. The shunt method is also frequently referred to as *parallel* feed, the terms "shunt" and "parallel" being used interchangeably. Either method is satisfactory in practical application, although the series arrangement seems to be in greater favor. In the shunt method there is no d-c voltage present in the r-f circuits, and this eliminates a possible hazard to the operator who might inadvertently get across the high d-c voltage when working near the coil.

TRANSISTOR OSCILLATORS

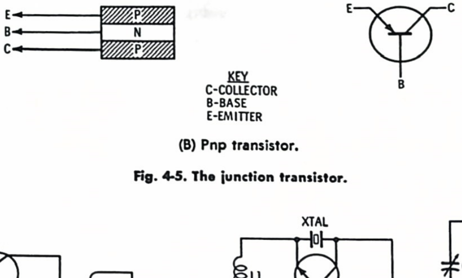
4-10 Transistors, since their introduction to the radio field, have rapidly taken a significant place in the industry. Their ability to perform as detectors, oscillators, and amplifiers in the same way in which a vacuum tube is used, immediately brought them to prominence. Their exceedingly small physical size plus the fact that they require minute amounts of d-c current has made possible the construction of radio broadcast receivers comparable in size to that of a cigarette package.

4-11 The radio amateur, ever eager to pursue experimentation with any new device introduced into his hobby, was quick to discover the great versatility which the transistor offered in transmitter design and construction, particularly in the portable and low-power applications. Small, low-voltage batteries could supply all of the power necessary for effective operation. No filament supply source was required, thus eliminating a heavy and bulky transformer as well as a filament which generates heat and is subject to occasional burnout. The major use to which the ham soon began putting these little "buttons" was in r-f oscillator and a-f amplifier applications. As an oscillator, since they required such a very minute amount of current on their input side and the battery source supplied more than adequate power on the output side, it was possible to "borrow" a bit of the output power with which to energize the input to produce and sustain oscillation.

4-11 While several types of transistors were developed and many more are being experimentally manufactured, factory production for public distribution is mainly in the point-contact and junction types. The former presents some manufacturing problems which are being met to some extent, but the junction type currently is by far the most popular among the amateur fraternity. A thin plate of highly refined germanium forms the heart of the junction transistor. Carefully measured amounts of chemical impurities are introduced in layers into the germanium to provide three regions of conductivity to each of which a wire lead is attached for external connections. If the chemical impurity so introduced is rich in electrons, the germanium is known as the *n* type. Low electron content labels the mineral as of the *p* type. This deficiency in electron content of the chemical is also referred to as *holes* in the germanium. The three points of contact are labelled as *base, collector,* and *emitter* and are so shown in Figs. 4-5A and B. Connection of the terminal wires to the three conducting lay-

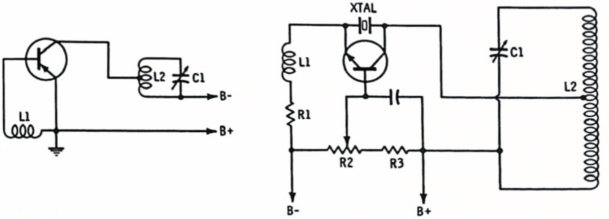


(A) Npn transistor.



(B) Pnp transistor.

Fig. 4-5. The junction transistor.



(A) Tunable transistor oscillator.

(B) Crystal-controlled oscillator.

Fig. 4-6. Transistor oscillator circuits.

ers in the germanium is shown in the illustrations. Dependent on the arangement of the p and n laysers, transistors are labelled as the *pnp* or the *npn* type; either is perfectly suitable for amateur application. Figs. 4-6A and B show two oscillator circuits using transistors.

4-12 R-F OSCILLATOR QUESTIONS

1. What is the purpose of a radio-frequency oscillator in an amateur radio transmitter?

Ans. To generate electrical oscillations at selected radio frequencies which will be radiated into space either with or without amplification.

2. Name two types of oscillators which produce the above results.

Ans. Quartz-crystal oscillators and self-excited oscillators.

3. What is the physical makeup of a quartz crystal?

Ans. A thin wafer sawed from pure natural quartz and ground to a thickness representing the frequency at which it is desired that it oscillate. These are approximately ¾″ to 1″ square.

4. How is contact made with such crystal wafers?

Ans. They are mounted between metallic plates in a hollow rectangular container of an insulating material. The plates are in turn connected to pin-type prongs protruding externally from the case thus providing connection to a circuit. Light spring pressure on the plates presses them against the surface of the crystal. Some containers have a metal shell which is insulated from the internal contact plates.

5. Do such crystals vibrate mechanically?

Ans. Yes, when electrical energy is applied, but such vibration is not discernible to the naked eye.

6. Name the two most popular forms of the self-excited oscillator.

Ans. In most general use are the Hartley circuit and the Colpitts arangement (Figs. 4-1E and B).

7. What is meant by the term "vfo"?

Ans. A vfo is a variable-frequency oscillator of the self-excited type. By proper design and adequate shielding a vfo can be made as stable as the crystal type of oscillator.

8. What is the distinction between "series" feed and "shunt" or parallel feed?

Ans. In series feed, the d-c plate voltage passes through all or part of the tuning inductance before reaching the plate of the tube. In a parallel- or shunt-fed circuit, the plate voltage is prevented from reaching the tuning inductance by means of a blocking capacitor.

9. What is one advantage offered by shunt feed?

Ans. Inasmuch as no high-voltage direct current appears on the tuning inductance, no hazard is presented to the operator should he accidentally come in contact with the coil. Also the rotor of the variable capacitor may be grounded.

10. How would you recognize a schematic diagram of a Hartley oscillator?

Ans. By a single tuning capacitor and a tapped tuning inductance.

11. What would identify a Colpitts circuit schematic?

Ans. The two tuning capacitors and an untapped inductance.

12. How is a Pierce crystal oscillator circuit identified?

Ans. By lack of any variable tuning capacitor or inductance.

13. What are the two most common types of crystal cuts used in amateur crystal oscillators?

Ans. The "X" cut and the "Y" cut.

14. Is the oscillation frequency of a crystal confined only to that frequency for which it is ground?

Ans. No; a number of harmonic frequencies of less amplitude appear.

15. Are such harmonic frequencies beneficial or otherwise?

Ans. Advantage can be taken of such harmonics in frequency multiplying. Those not used in this manner should be suppressed, which is accomplished by proper circuitry and adjustment in the following transmitter stages.

16. What power-handling capability does a crystal oscillator offer?

Ans. A crystal oscillator is normally operated at a low power level; 5 to 30 watts input to the tube plate circuit is an accepted average. It is possible, by careful adjustment, to use powers of the order of 50 to 75 watts.

17. Of what material are transistors used by amateurs generally composed?

Ans. The majority of transistors for amateur use are manufactured from germanium crystals.

18. What is introduced in such crystals in the manufacturing process?

Ans. Chemical impurities in three layers to provide three regions of conductivity.

19. How is contact made with these conducting layers?

Ans. By the introduction of small wires the outer ends of which are brought out through a seal for external connection.

20. What is the general term used to describe a transistor used in amateur applications?

Ans. While other types of transistors are manufactured, those most commonly used in amateur practice are designated "junction transistors."

21. Are all junction-type transistors identical? If not, explain.

Ans. No; both the pnp and the npn types are used in amateur work.

22. Are junction-type transistors capable of generating oscillation?

Ans. Yes.

23. Describe the pnp-type transistor.

Ans. In a pnp transistor, the two outer layers have low electron content, sometimes referred to as "holes." The center layer is rich in electron content.

24. Describe the npn-type transistor.

Ans. In an npn type, the two outer layers are rich in electrons whereas the center conducting layer is deficient.

25. How are the terminal wires from the conducting layers labelled? Show by simple sketch.

Ans. Use Figs. 4-5A and B to indicate this.

CHAPTER 5

Frequency Multiplication and R-F Amplification

5-2 In the preceding chapter frequency multiplication was mentioned in connection with oscillators. With proper circuitry and components, frequency multiplication is an important adjunct to radio-frequency transmission. A large proportion of the amateur bands are in harmonic relation to each other. For example, a frequency in the band embracing 3.5 to 4.0 megacycles inclusive can be *doubled* with proper component and circuit arrangement to produce the second harmonic of the oscillator stage. If the frequency selected as the fundamental in the lower band lies between 3.5 and 3.65 mc, its second harmonic will fall between 7.0 and 7.3 mc, which are the legal limits of this higher-frequency band for amateur operation. Similarly, if the fundamental of the oscillator circuit is between 7.0 and 7.175 mc, doubling the frequency in this range will permit operation in all of the next higher or so-called 20-meter band, which is limited to 14.0 to 14.35 mc inclusive. Using a fundamental frequency of 7 to 7.3 mc, it is possible by *quadrupling* to use the fourth harmonic of the fundamental and realize legal operation in the 10-meter amateur band (28.0 to 29.7 mc).

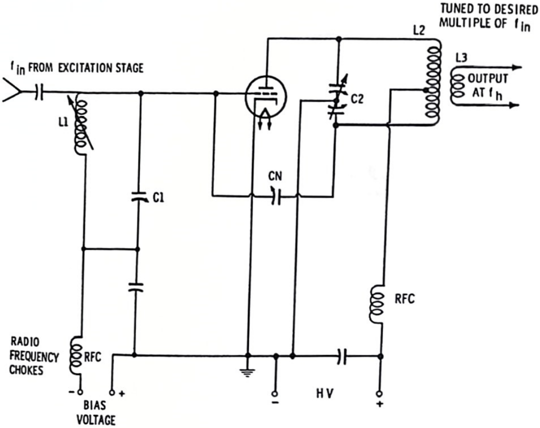
5-2 A fundamental oscillator frequency between 7.0 and 7.15 mc can be *tripled* to operate in the 15-meter band by using the third harmonic of the fundamental oscillator frequency. As the frequency is increased by multiplying, the resultant output becomes proportionately less. The most common practice is to double or triple frequencies below the 10-meter band, although quadrupling from the 40-meter to the 10-meter band is also quite common. Multiplication of the lower fundamental frequencies *can* be carried out to five, six, or even more times, but with an increasingly lowered output which is of little if any value for exciting following stages unless a number of amplifiers are employed. The cost of components and the greater complication of circuitry and adjustment make such multiplication generally impractical except for special applications.

5-3 Multiplication then to the third and possibly even the fourth harmonic can be considered to be about the practical limit for useful application in amateur communication in the bands between 10 and 160 meters. For the higher-frequency bands of 6 and 2 meters or 50.0 to 54.0 mc and 144 to 148 mc, none of the lower-band frequencies can be multiplied to fall within legal limits. It is necessary therefore to choose a frequency which can be doubled, tripled, or quadrupled to fall within the boundaries of these two bands. Fundamental crystals can be purchased for these higher frequencies, but they are relatively costly. A suitable vfo can be purchased or built to cover these bands. Use in the vhf bands of a transmitter designed to function on the lower frequencies is, of course, possible, but it introduces a number of losses, such as long leads, dead-end inductances, and oversize variable capacitors. These all contribute to some inefficiency and call for extremely careful and accurate tuning adjustments. Amateur practice more commonly uses an entirely separate transmitter to cover the 6- and 2-meter bands. The same power supply used with a lower-frequency transmitter can, however, serve the additional transmitter as well. Many amateurs use a simple switching arrangement to apply power to either transmitter at will.

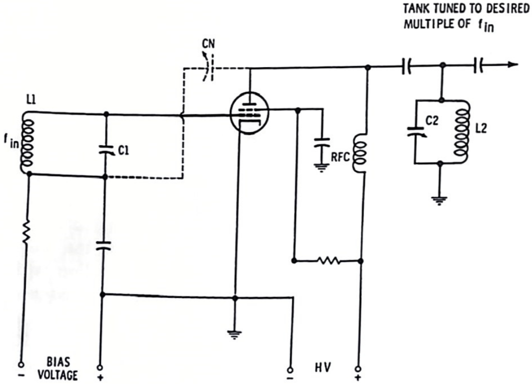
5-4 Circuits involved in frequency multiplication are shown in Fig. 5-1. As with oscillators, either shunt or series feed from the plate supply source can be used. Frequency multipliers also serve to amplify the output of the oscillator or "driver" stage. Such amplification is generally relatively small, inasmuch as frequency multipliers are ordinarily operated at power inputs somewhat lower than the capabilities of the tube chosen for this function. By such operation, greater frequency stability is attainable than if the tube is operated at its maximum power rating. One or more amplifier stages designed for that express purpose and not used to multiply their input frequency are more desirable. These may be operated at their maximum rating; they are referred to as *intermediate* or *buffer* amplifiers, sometimes termed *straight-through* amplifiers; the terms are interchangeable. The "buffering" effect which they provide serves to reduce any unwanted harmonics or other spurious r-f generation from preceding stages, which might reach the final amplifier. Tubes selected for either frequency multiplication or straight-through amplification should preferably be of the tetrode or pentode types by reason of their small interelectrode capacitance when properly connected in the circuit. This serves to greatly minimize and often eliminate the necessity for neutralization. Such tubes also require less exciting power from a previous stage, which condition also contributes to greater frequency stability and to the reduction of undesired harmonics.

INTERMEDIATE AMPLIFIERS

5-5 In the preceding paragraph it was mentioned that the terms straight-through, intermediate, and buffer amplifiers were one and the same. Regardless of how termed, such an amplifier is generally considered to be one that follows a stage which generates an initial fundamental or harmonic frequency which the straight-through amplifier receives and passes through to its output without multiplying. In other words, it simply receives an input frequency at a relatively low power level and passes the same frequency to its output at increased power. The output can serve to feed an additional straight-through amplifier, or it can, as in most of the lower-powered transmitters, feed directly into the antenna circuits. Used in this latter manner, it is more correctly termed a *final* amplifier; this phase of amplification will be discussed in the following paragraph. In addition to the amplifying function which a straight-through amplifier performs, it also introduces the buffering effect previously mentioned in that it tends to attenuate any harmonics or spurious radiation which may attempt to pass through it from the preceding stage. An intermediate amplifier is also referred to frequently as an *isolation* stage as it tends to "isolate" the following stages of a transmitter from unwanted harmonics and parasitic generation. Actually,



(A) Triode tube with neutralization (CN).



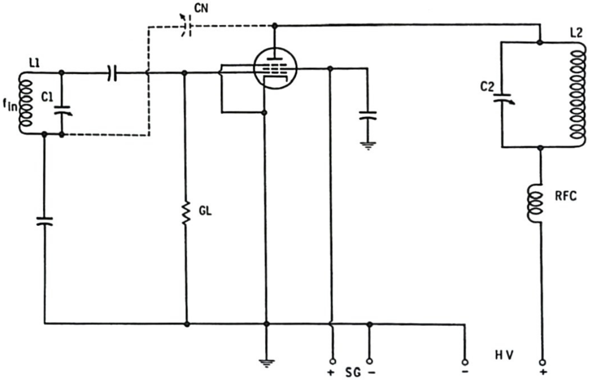
(B) Tetrode tube with CN optional.

Fig. 5-1. Frequency-

this is just another way of saying that it buffers or chokes back such unwanted characteristics.

THE FINAL AMPLIFIER

5-6 In considering this subject we again run into interchangeable designations; the *final* amplifier, which is always accepted as the transmitter stage that feeds directly into the antenna system, is also known as a *power* amplifier. Actually the term "final" is a bit more appropriate; *any* amplifier stage can be considered a "power" amplifier, since that is really the purpose of all amplifiers. They simply increase, or amplify, the amount of power fed to their input before passing it to the next stage. So, final amplifier is a more fitting designation for that stage which serves to excite the antenna; either term is readily understandable, however. Final amplifiers can con-



(C) Pentode tube with CN optional.

KEY TO SYMBOLS

C1---- GRID TUNING CAPACITORS
C2---- PLATE TUNING CAPACITORS
CN---- NEUTRALIZING CAPACITORS - (USUALLY NOT REQUIRED WHEN STAGE IS USED AS A MULTIPLIER)
L1---- GRID INDUCTANCES
L2---- PLATE TUNING INDUCTANCES
L3---- COUPLING COILS
RFC---- RADIO-FREQUENCY CHOKES
GL------ GRID LEAK
SG------ SCREEN-GRID VOLTAGE
HV------ HIGH VOLTAGE

multiplier circuits.

sist of any of the circuits shown in Fig. 5-1. Neutralization is almost *always* desirable in final-amplifier stages.

5-7 Inasmuch as the final amplifier is the generator of the amount of power applied to the radiating system, it is obviously designed to operate at an input wattage at a value as high as is practical in order to realize the most from a transmitter. When the term "practical" is used, it means that there are limiting consideration which must be noted. One is the tube itself which is chosen for this important function. It will have a certain definitive maximum-voltage and current limitation which may safely be applied to its various electrodes. To exceed either of these manufacturers' ratings is to overload the tube. While this is often done in the amateur field and present-day tubes are rugged enough to take it within reason, it is really not a desirable practice. Increased heat generation from the outer surface of the tube envelope can influence other components in the transmitter, frequently causing some detuning of the circuits.

Higher-than-rated plate voltage and current with the consequent excessive heat developed *within* the envelope can so affect the elements as to cause the tube to take off on a tangent and go into self-oscillation at a frequency which falls outside of the amateur bands. Such spurious frequencies are not only wasted by contributing nothing to radiation from the antenna on the legal frequency produced by the oscillator and its multipliers, if any, but such out-of-band operation can well cause interference with commercial and other radio services. When it is considered that the few watts additional power gained by overloading a tube is most often simply wasted by lowering the efficiency of the final stage as a whole and probably creating interference which will doubtless bring an FCC citation, it hardly seems worth while. Better to stick to the manufacturers' recommended ratings with much better assurance of legal and trouble-free operation.

NEUTRALIZATION

5-8 While triode tubes (3 elements) are frequently used in frequency multipliers and amplifiers, they are not the most desirable, inasmuch as the internal capacitance between the grid and the plate electrodes greatly increases the tendency of the circuit to oscillate at unwanted or spurious frequencies.

A great deal of this undesirable effect can be "swamped out" through *neutralization.* This term is exactly what the word implies; the internal capacitance of the tube elements can be neutralized by introducing a small variable capacitor in the circuit; this is shown diagrammatically in Fig. 5-1. Obviously, wherever triode tubes are used as frequency multiplier/amplifiers, a neutralizing capacitance is dictated for most effective performance. This adds some complication to the adjustment of each stage, and this must be carefully performed to balance out the internal tube capacitance to the greatest degree possible. Physically, not much is involved; merely the addition of a small variable capacitor mounted as closely as possible to the tube and connected as shown in the illustration. Ordinarily, once neutralized the circuit needs no further adjustment of this kind, unless the tube is changed.

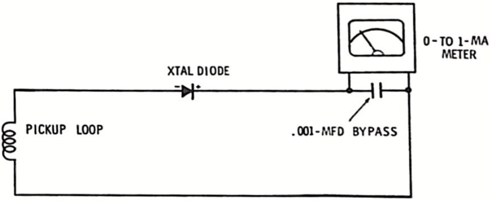


Fig. 5-2. Neutralizing-indicator circuit.

5-9 Perfect neutralization is seldom achieved, but for all practical purposes, adjustment to approach complete neutralization as closely as possible is adequate. The only adjustment required is that of the neutralizing capacitor itself and a slight touching up of the output-tank tuning as neutralization proceeds. The tube filament must be lit and excitation from the preceding stage applied, but the plate voltage must be *off*. Some type of neutralizing indicator must be provided (Fig. 5-2) ; these are simple devices consisting only of a 0- to 1-ma d-c milliammeter in series with a crystal diode and a coupling coil of a few turns. A bypass capacitor (.001 mfd) is shunted across the meter. The coil is coupled to the amplifier tank coil and temporarily fixed in a position which will not permit too much pickup to damage the meter or the diode. The tank capacitor is swung through resonance and the neutralizing capacitor adjusted until the minimum deflection of the meter is obtained.

5-10 A grid meter or combination grid-plate meter is customarily built into the final stage of most transmitters (Fig. 5-3). This provides a convenient means of neutralization. Preceding amplifiers and multiplying stages will generally require a separate neutralizing indicator such as described in the preceding paragraph. Using the grid meter of the transmitter (*with plate voltage disconnected*), the neutralizing capacitor is carefully adjusted to cause a minimum variation of the reading on the grid meter when the plate tank circuit is tuned through resonance. For each adjustment of the neutralizing capacitor, the plate tank circuit is retuned to maintain resonance. The goal is to attain the lowest possible reading of the grid meter while maintaining resonance in the plate tank. Plate voltage may then be turned on and a further slight adjustment of the neutralizing capacitor made to produce minimum plate current and maximum grid current simultaneously at resonance. The ideal point is reached when the grid current falls off slightly on either side of resonance.

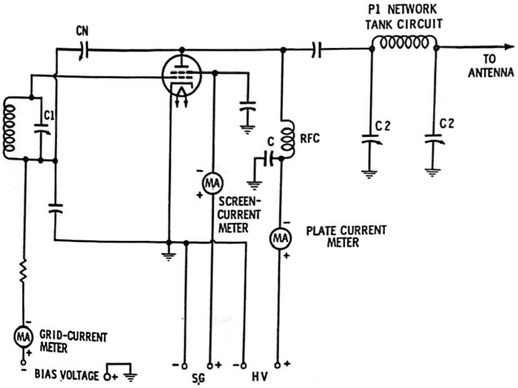


Fig. 5-3. Commonly used metering circuits for a final amplifier.

5-11 Screen-grid tubes by reason of the screening effect of the additional grid interposed between the plate and the control grid require little neutralization. This is frequently ignored in the lower-power stages, but neutralizing of the final amplifier tube is highly desirable to provide every assurance that self-oscillation in the tube will not take place (often at illegal frequencies) or that the possibility of such is at least minimized to the greatest extent possible. The neutralizing procedure is identical with that described in paragraph 5-9 for triodes. Connections of the neutralizing capacitor in different circuits of screen-grid tubes are illustrated in Figs. 5-1B and 5-3. Various metering points in a final-amplifier circuit are also shown in Fig. 5-3.

GRID BIAS

5-12 Grid bias is nothing more than a relatively low negative voltage applied to the grid of a tube to protect it from drawing excessive current in the event that excitation fails. In the smaller tubes this voltage is most frequently supplied by the voltage drop across a small resistor in series with the cathode and across which a fixed capacitor is shunted. Such a capacitor should have a value of anywhere between .01 mfd and .001 mfd for radio-frequency tubes. In biasing tubes used in audio circuits a much higher value (from 10 to as much as 50 mfd) is employed. The bias voltage can be said to act as a "control valve" on the plate current since increasing the negative voltage on the grid decreases the plate current. By increasing the negative voltage on the grid to a point where the plate current has fallen to zero, the tube is said to be biased to *cutoff*; this condition, particularly in radio-frequency amplifiers, is taken advantage of since its tendency is to increase the efficiency of such amplifier.

5-13 Supplying the grid with negative voltage from the cathode, as described in the preceding paragraph, is not the only source from which negative voltage for the grid can be secured. A simple grid-leak resistor connected from grid to ground through a radio-frequency choke will supply *operating* bias without protection from tube-plate overload, should excitation fail. Placing a battery in place of the grid leak with the negative terminal connected to the grid and the positive terminal grounded will provide *both* operating and protective bias. However, many hams are inclined to balk at using a battery for this purpose. While this system is satisfactory, it does become gradually less effective as the battery ages and deteriorates. A small conventional power supply can be built up using a transformer of the broadcast-receiver type which has relatively low plate-voltage windings. Either a vacuum-tube or silicon-diode rectifier can be used to feed a small filter system. The negative output of the filter system will connect to the grid, the positive side being grounded. The specified negative voltage for the grid can be secured from a dropping resistor. Another arrangement sometimes used if the power transformer of the main voltage supply has an unused filament winding, is to use this winding to supply the low voltage side of an additional filament transformer. In turn, the winding normally connected to the 115-volt a-c power source is used as the "high-voltage" secondary. Regardless of the source of negative bias voltage for the grid, bias *must* be supplied or damage to the radio-frequency tube will result.

5-14 RADIO-FREQUENCY STUDY QUESTIONS

1. What is meant by the term "frequency multiplication"?

Ans. Frequency multiplication means that the fundamental frequency of the r-f oscillator circuit is multiplied by 2, 3, 4 or more times as selected, through adjustment of the frequency multiplying stage(s) in a transmitter.

2. Are all frequencies within all amateur bands harmonically related to those in other amateur bands? Explain briefly.

Ans. No; only certain portions of various bands can be multiplied in frequency to fall within the limitations of other amateur bands.

3. Desiring to "triple" or use the third harmonic of a fundamental oscillator frequency to generate a frequency of 21.015 mc, what would be the fundamental frequency of the r-f oscillator?

Ans. 7.005 mc. (See appendix B.)

4. Would both the fundamental and the third harmonic frequency in the above question be within the legal amateur band limits?

Ans. Yes.

5. What is considered to be the practical extent to which frequency multiplication can be carried in amateur practice?

Ans. Quadrupling or using the fourth harmonic is the generally accepted practical limitation for amateur use.

6. Do frequency multiplying stages also serve as r-f amplifiers? If so, to what extent?

Ans. Yes, although amplification is generally at a relatively low level, as frequency multiplying stages are generally operated at powers somewhat lower than the rated capacity of their tube(s) in the interests of better frequency stability and attenuation of unwanted harmonics.

7. May more than one stage of "straight-through" or "intermediate" r-f amplification be employed in a transmitter?

Ans. Yes.

8. If more than one such amplifier may be so employed, what is the practical limit to the number of such stages? Explain briefly.

Ans. Theoretically, any number may be used; from the practical standpoint, however, two or three stages of r-f amplification is the commonly accepted limitation in amateur service. Cost of components, complication of circuitry, availability of adequate tubes, and maximum power limitations (1000 watts input) in the amateur service dictate use of two, or at most three such stages.

9. How does a "final-amplifier" differ from an "intermediate" or "buffer amplifier" stage?

Ans. Basically, there is no difference. Practically, final amplifiers are generally operated at or close to the maximum rating of the tube(s) in that stage; intermediate amplifiers are ordinarily operated somewhat below maximum ratings. Any intermediate amplifier may serve as a final amplifier if its output is coupled to the radiating system rather than to a following stage of amplification.

10. Do final-amplifier stages require neutralization? If so, why?

Ans. This is dependent on the tube(s) chosen to serve in this stage. A tetrode or pentode, by reason of the screen grid present in its envelope, will ordinarily perform satisfactorily without external neutralization. Where any suspicion that unwanted harmonics or spurious frequencies may leak through the final stage to the radiating system may exist, application of a slight amount of external neutralization is desirable.

11. What purpose does neutralization serve in a triode-tube circuit?

Ans. Neutralization external to the tube will, to a large degree, cancel out the interelectrode capacitance of the tube elements thereby greatly reducing the chance of harmonic- and spurious-frequency generation.

12. In transmitters equipped with a meter by which both plate and grid currents can be read, what relationship between the two current readings would indicate theoretically perfect neutralization?

Ans. *Minimum* plate current (proper tuning "dip") and *maximum* grid current should occur simultaneously at circuit resonance. With this condition, the grid current should fall off slightly when the circuit is tuned to either side of resonance.

13. How is the point of maximum neutralization determined using only a grid-current meter?

Ans. With the plate voltage disconnected from the tube but with excitation applied to the grid, the neutralizing capacitor is adjusted to a point where the grid meter will show minimum or no deflection when the plate circuit is tuned through resonance.

14. Name another means by which neutralization may be checked.

Ans. A simple neutralization indicator can be made up of a 0-1 milliammeter in series with a crystal diode and a coupling coil of a few turns. Placing the coil in the r-f field of the stage to be neutralized, the tank condenser is swung slowly through resonance and the neutralizing capacitor adjusted to the point where the meter of the indicating device shows no movement at circuit resonance.

15. What is "grid bias"?

Ans. Grid bias is a relatively low negative voltage applied to the grid of a tube (from 0 to −600 volts depending on tube type).

16. Name four sources from which such bias voltage can be obtained.

Ans. (A) From a battery; (B) "self bias" from the voltage drop across a small resistor in series with the cathode of the tube; (C) from a separate small power supply; (D) from a so-called "grid-leak" resistor connected from the grid of the tube to ground.

17. What does the term "cutoff bias" signify?

Ans. The amout of negative voltage applied to the grid which will cause the plate current to drop to zero when no excitation is supplied to the grid of the tube.

18. Name one objection to the grid-leak system of biasing.

Ans. Grid-leak bias is merely an *operating* bias. Should excitation suddenly be cut off from the tube with the plate voltage still applied, the plate current would immediately become excessive and could damage the tube.

19. What is "protective" bias?

Ans. Bias supplied from a source other than a grid leak not only serves as an operating bias but functions to protect the tube from damage in the event of excitation failure by immediately dropping the plate current to cutoff or zero.

20. What other term is often used interchangeably with "final" amplifier to designate the r-f stage feeding into the radiating system?

Ans. The final amplifier is often referred to as the "power" amplifier since it represents the last and highest powered stage of the transmitter.

CHAPTER 6

The Radiating System

6-1 There are probably not *quite* as many antenna types as there are amateurs, but there *are* literally hundreds of radiating systems of good, bad, and indifferent design. Many of these have been ingeniously devised to produce rather excellent results. Others are more or less compromise arrangements adapted to space limitations or to prove or disprove a pet theory of the designer. Antennas of what may be called the "freak" variety are often described in various publications. Basically all are the same in that they employ elevated wires, rods, pipes, towers, and similar metallic structures which serve to radiate into space the r-f energy developed by a radio transmitter. In a publication of this type, only those of more conventional design which reflect good engineering practice and which have proven effective in operational use can be considered. Any questions on radio-frequency radiating systems which you may be asked in the Advanced- and Extra-class license examination will be based only on these types.

THE SIMPLE WIRE ANTENNA

6-2 In its earliest days "wireless" (now called radio) transmission was accomplished by radiating the radio-frequency signal from an elevated configuration of wires variously supported as high as was practical. Marconi leaned heavily toward a fan-like arrangement hung from a triatic stay which was in turn supported between tall masts. Many early amateurs followed this pattern, and the so-called "fan" antenna enjoyed several years of popularity in amateur application. Radio hams, however, being inherently experimenters, tried numerous other configurations. Final acceptance in popularity was accorded the multiwire arrangement whereby four, six, or even eight wires spaced a foot or more apart and as long as physical limitations would permit, were stretched between wooden or pipe spreaders, or spars. The grid work thus formed was then hoisted between two supports as high as possible above the ground. Sometimes all wires were connected in series; in others they were paralleled at each end of the span. From either end, in the center, or at an intermediate point, *lead-in* wires were brought down to the transmitting equipment. Such lead-ins were sometimes twisted together forming what was then referred to as a "rat-tail." In other antennas, a wire was brought down separately from each of the horizontal-span wires and the lead-in was not bunched until just before entering the transmitter building. Antennas of this type were the rule rather than the exception in the era preceding World War I.

6-3 As a result of increased engineering knowledge and accelerated development to meet combat conditions, it was soon found necessary to discard the awkward and unwieldy multiple-wire antenna, particularly for field operations. Initial tests indicated that a *two-wire* elevated structure performed every bit as well as one with a greater number of wires. Reasoning based on this development soon led to experiments with a *single wire*; again completely satisfactory results were achieved. As a consequence, following the cessation of hostilities and the lifting of restrictions on amateur radio operations, the amateur camp became divided. Proponents of the single wire argued loud and long but a number of "die-hards" still clung to the multiwire antenna in various forms. It was not long however before the unbelievable results achieved in long distance transmission by using a single-wire radiator, particularly with the rapidly increasing popularity of vacuum-tube transmission which was then exciting the radiocommunication world, caused a rapid swing to the single wire. This was not only true in amateur practice, but many shipboard installations by commercial operating companies adopted a single wire strung between the masts. Radio results proved every bit as good as with multiple-wire arrangements; spreaders and their sway guys, as well as a number of then costly insulators, could be eliminated. The eventual result, which is evident today, was the complete adoption of a single elevated wire by the greater majority of the amateur fraternity. Initially, these antennas were of random length; and the lead-in, which we now refer to as the *feeder*, was taken off either at one end, in the middle, or at some intermediate point convenient to bring it to the transmitter location in as short and direct a line as possible. An antenna of this type is shown in Fig. 6-1A. Fig. 6-1B represents a variation often used successfully where it is impossible to erect two masts, poles, or towers, or to use one or more existing elevated supports.

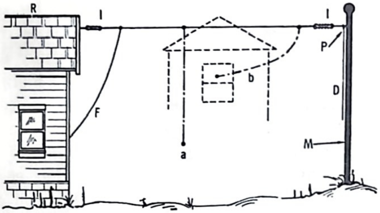
6-4 Experiment and consequent development soon brought forth the *resonant* wire antenna. The term represents a single-wire antenna cut to a definite length representing a full, half, quarter, or sometimes even an eighth wavelength. Through such dimensioning along with improved methods of feeding these radiators, radiation efficiency was greatly increased, and the resonant antenna is almost universally used today, although many of the newly licensed Novice-class amateurs start with a single random-length wire as shown in Figs. 6-1A and 6-1B. Feeding the r-f output of the transmitter to these wire-type radiating systems is now accomplished in a number of ways. The "off-center-fed Hertz" antenna, for example, which is sometimes called the *Windom* in recognition of the amateur who brought it into prominence, uses a single-wire feed taken from the horizontal span at a calculated point 14% from the center (Fig. 6-1D). Another type of feed line was patterned after that originally devised for use on Zeppelin lighter-than-air craft and dubbed *Zepp-feed* by amateurs. This antenna employs *two* wires separated by insulated spacers as a feed line from the transmitter proper to the antenna. It is connected to the antenna at one end (Fig. 6-1C). Two-wire lines connected to the center of the horizontal radiating portion are also very popular. These may take the open-line or Zepp form, coaxial cable, or a line similar to that used for TV lead-ins of the ribbon type, generally referred to by the manufacturers' trade name of *Twin-Lead.* While any of these lines serving to supply the antenna with r-f energy are "feeders," they are termed *transmission lines* as well, either term being perfectly applicable and acceptable. Antennas fed with these various lines are indicated in Figs. 6-1C, E, and F.

VERTICAL ANTENNAS

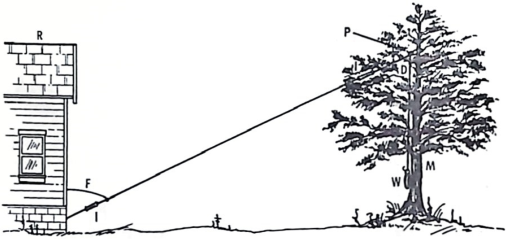
6-5 In vertical antennas, quite a departure is taken from the horizontally supported single-wire radiator. For a number of years, starting in about the late 20's, radio broadcast stations experimented with and soon adopted what were rightly termed *vertical radiators*. Whether such antennas were initially developed by commercial interests or whether they can be traced back to some obscure amateur experimentation is an open question. At any rate, almost without exception, broadcast stations and other commercial and government communications interests now use vertical self-supporting tower structures as their radiating element for radio transmission; these towers are sometimes grounded and sometimes insulated at the base. True, some amateurs had successfully used a vertically suspended wire as a radiator with considerable success prior to commercial developments, but they were still wire antennas requiring a high upper support. Towers commercially made for amateur use were beginning to tentatively enter the field, but they were initially rather costly, bulky, and heavy to ship and difficult to assemble and erect; they were slow to gain a minor measure of popularity. Nevertheless, with the excellent proven performance of such metallic structures in the commercial radio-transmission field, the amateur, always resourceful, began to cast about for reasonable substitutes. Soon many a farmer realized an unexpected windfall through the sale of an abandoned windmill tower. These were usually disposed of cheaply, and the deal generally involved the ham taking them down, which gave him a measure of experience on which to draw for re-erection at his own site.

6-6 Self-supporting towers, such as the windmill type, were not always available, however. For radio, the shape and form of a tower structure meant nothing; it was the radiating proptries of the metal that counted. So water pipe, electrical conduit, and later well-casing and irrigation pipes were not long in taking unaccustomed positions by standing on their ends. They required guying, but so did the average mast for a wire antenna; this presented no more of a problem. Whether to insulate the base, or ground it, was a matter of individual opinion. Numerous ingenious insulators were devised; milk and soft-drink bottles were sometimes pressed into use. Power and telephone company construction crews learned not to leave "petticoat" insulators lying in the weeds around a pole overnight. Most hams insulated the base with the thought of trying it both ways; an insulated mast could be easily changed to a grounded type with a battery clip lead and a ground rod or equivalent piece of pipe without lowering the radiator.

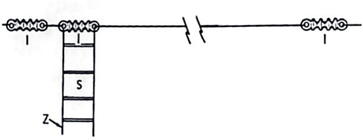
6-7 Height became a bit of a problem. A full-wave vertical was a bit out of the question, since it required some 260 feet straight up in the sky for the amateur 80-meter band. This was not much different from the problems the wire antennas posed, although horizontal-wire erection where the space was



(A) Random-length wire.



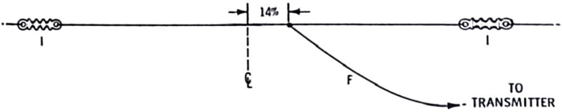
(B) Sloping random-length wire.



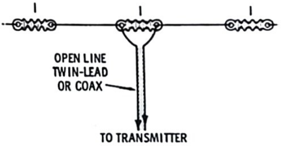
(C) End-fed half-wave with open-line feeders.

Fig. 6-1. Convenavailable for a 260-foot stretch, was a lot simpler than "shooting for the moon" with a slender pipe; anyway, use of full-wave radiators was just about a thing of the past. A half wavelength on 80 still called for about 130 feet of pipe standing on end for the 80-meter band and a large multiturn loading coil for 160.

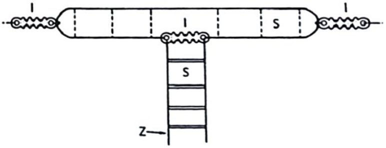
Still, 130 feet was a "pretty scary" piece of pipe to erect—how about a *quarter* wave? Most broadcast stations were using this, and the engineering designs for loading coils had progressed to considerably increase their efficiency. That was



(D) Off-center-fed Hertz or "Windom" antenna.



(E) Center-fed dipole antenna.

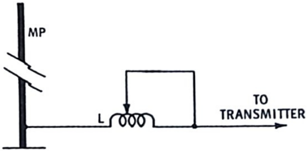


(F) Folded dipole with open-line feeders.

KEY TO SYMBOLS:

R-HOUSE ROOF
I-INSULATORS
F-LEAD-IN WIRE
P-PULLEY
D-DOWN-HAUL
M-MAST OR TREE
W-WEIGHT

S-INSULATED SPACERS
Z-ZEPP FEEDERS
TW-TWIN-LEAD
MP-METAL MAST
L-ADJUSTABLE LOADING COILS
a and b - ALTERNATE FEED POINTS

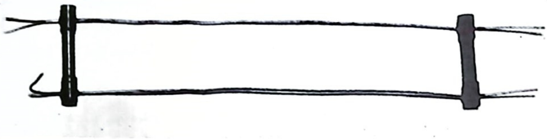


(G) Base-loaded vertical radiator.

tional antennas.

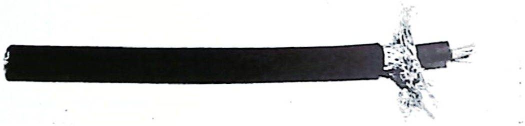
more like it; 65 feet or so for a quarter-wave vertical *could* be handled (with a bit of doing and a *lot* of guying), and a surprising number of hams did it. Many more, however, were

(A) Single open line for antenna and lead-in.

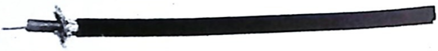


(B) Two-wire open-line "Zepp"-type feeder.

(C) Molded ribbon two-wire twin-lead line.



(D) RG-8/U coaxial cable.



(E) RG-58/U coaxial cable.

Fig. 6-2. Transmission-line types.

inclined to shorten this to maybe 40 or 50 feet. This shortened length required more loading coil, but with the remarkable results beginning to be accomplished on the higher frequency bands of 40, 20, 15, and 10 meters, 80 meters was commencing to lose some degree of popularity, particularly as a DX band.

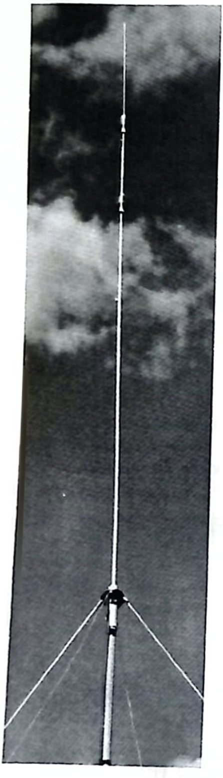
More pondering involved the consideration that a 40- or 50-foot piece of pipe was again a random-length antenna rather than a resonant type. It was soon decided that it would be better to make it a quarter wave on 40 meters and load it heavily for 80 and 160 meters. Soon 33- to 35-foot pipes were springing up across the nation like stalks of corn in a farmer's field. With the improvement in loading coils and r-f feeding methods, a quarter wave on 40 meters gave surprisingly good results, even with heavy loading for 80 and 160. Today, among the vertical adherents who swear by this type of radiator, a literal forest of these antennas is found throughout the land. Manufacturers have also developed many types of verticals, varying in length, methods of loading, etc., and most of their offerings perform very well (Fig. 6-3).

Commercial towers, while still available, enjoy little acceptance as amateur radiators, particularly in the self-supporting and necessarily costlier types. Some which require guying are in use, of course, but merchandising of towers now falls mainly in the field of support structures for rotary beam antennas. Prices are still a bit steep, but the mass production of television antenna towers has done much to bring a tower of this type, whether as a vertical radiator or to support a beam antenna, into a more reasonable price class for the amateur.

DIRECTIONAL ANTENNAS

6-8 Directional radiating systems are basically of two types: fixed and variable. All of the wire types, whether suspended horizontally, slanted as in Fig. 6-1B, or hung vertically, can be considered as *fixed*. Likewise, the so-called *beam antenna* that is fabricated from pipe, tubing, or rods is considered to be fixed unless provided with some means of rotation about its axis. Beam antennas, by reason of the greater bulk required, are seldom used for the frequency bands below 14.0 mc, and almost invariably for the bands in which they are popular, they are arranged to be rotated either manually or electrically.

6-9 It can be said that *all* antennas, regardless of type, have a certain amount of directivity. With amateur installations of the simple wire types previously discussed and particularly on the lower frequency bands of 7.0 to 7.3 mc and below, *planned* directivity is seldom possible due to physical site locations. Planned directivity means the erection of the hori-



Courtesy Cush Craft

Fig. 6-3. A trapped vertical radiator.

zontal span in a direction which will take full advantage of whatever directivity the chosen type of antenna will present. This is, however, ordinarily a matter of little concern. Unless the amateur has a particular reason for concentrating as much of his radiation as possible in a particular direction, as, for example, desiring to reliably maintain a more or less permanent schedule with a distant station, there is little reason to pay attention to the directive properties of an antenna in the three lower-frequency bands. The average ham, rather than desiring a pronounced directive effect, is interested mainly in communication with the greatest efficiency in *all* directions. Most of the wire antennas will provide this rather well, although plotted field patterns will show definite directive effects. These however are not extreme and seldom introduce enough gain or loss in signal strength to be a matter of concern.

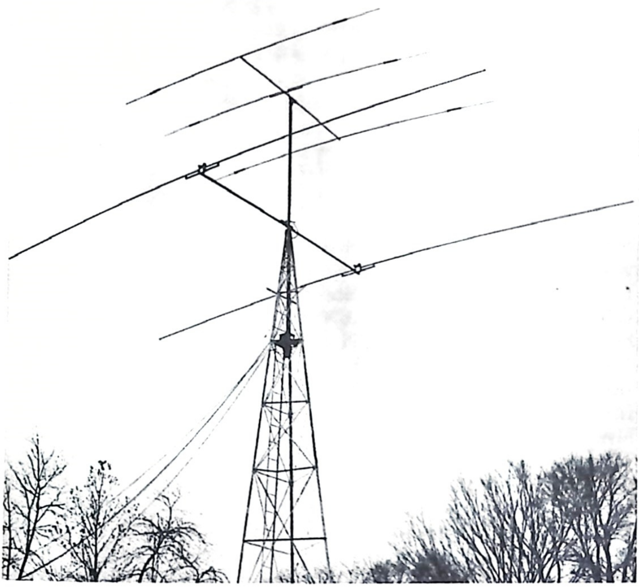
6-10 There is one exception in considering *all* wire antennas to have more or less minor directive effects. This is the *rhombic* antenna, which can be so designed and erected to produce rather good directional characteristics. This type of antenna, however, requiring, as it does, four supporting structures arranged in a diamond pattern and a rather large area to accommodate its much greater horizontal length and breadth as compared to more conventional antennas, sees relatively little usage by amateurs. While the rhombic is an excellent antenna, its physical dimensions restrict it to those hams who are fortunate enough to have some cleared acreage available for its erection. The major use of rhombics is in commercial service for long-distance high-powered transmitting stations.

6-11 Where antennas of any type must be erected in average residential areas, they are subject to another consideration which to some degree may offset a large part of any directivity they may possess. Almost without exception, the site at which they are erected is surrounded by a maze of power and telephone wires, other residences with perhaps tall television towers mounted on their roofs, perhaps apartment or office buildings towering many stories above the ham antenna. All of these create a shielding effect about the ham antenna site and act to absorb and eventually ground a certain amount of radiated energy. Some metallic structures may even be harmonically related to the frequency on which the amateur station is operated, thereby absorbing even more of the r-f radiation from the ham antenna. For conditions such as this, and they are average, about the only compromise is to erect the antenna at as great a height as possible and as much in the clear and away from surrounding objects as the area will permit.

BEAM ANTENNAS

6-12 To the casual observer the weird collection of pipes, rods, or tubes arranged in what to him is a fantastic pattern on a tower, mast, or roof top, resembles the "monkey-bar" configuration of pipes found in a children's playground area. To those who are "in the know," it is simply one of the many types and designs of the beam antenna of a ham radio station. Occasionally these are relatively simple with but a few elements and often installed in a fixed position. Most, however, are of the rotating type arranged to be moved about their axis. Some are simply turned in various positions by a lever at the base of a supporting mast or tower. Others may be so installed that they may be rotated right from the operating position by a hand wheel. The more elaborate installations include an electrical motor-driven rotator also controlled from the operating position. Regardless of the means of rotation, all of these movable types may be turned to any one of the 360 degrees of the compass. Beam antennas are highly directive and find great favor with the DX-minded amateur on the bands from 14.0 mc up through the higher-frequency bands. Establishing communication with a distant station to best advantage calls for positioning the beam directly toward him for maximum signal gain.

6-13 As with wire antennas, there are many types of beams which are called by various names. Common practice is to use a readily recognizable generalization which broadly classifies them as *two-*, *three-*, or *four-element* beams, depending on the number of elements used in their construction. Like wire antennas, beams are at their best when proportioned to perform most effectively in definite frequency bands. As the simple formulas for calculating length vs. frequency as used in planning wire antennas is of course hardly applicable to the rods, pipes or tubing of a beam, a bit of mathematics necessarily enters into proper design technique. The inductance and capacitance of the elements must be taken into consideration as well as the spacing between them. The design is worked out around these values to arrive at the final physical makeup to provide a resonant radiator in the band for which it is intended. Often multielement beams are *stacked*, or placed one above the other on the supporting structure (Fig. 6-4). Each such set of elements represents a different band; a three-stack



Courtesy Mosley Electronics, Inc.

Fig. 6-4. Tower-mounted stacked rotary beam antennas with electrical rotator.

array may, and often does, represent 20-, 15-, and, 10-meter beams separated vertically from each other at precalculated distances. Many beams are fitted with *directors* and often with *reflectors*. As the name implies, directors are simply elements so arranged as to "pull" the signal from the front of the driven element and direct it in the desired direction. Reflectors, on the other hand, serve to "push" the signal toward the front of the beam; both act to increase the level of the radiated signal toward the front of the beam.

6-14 Since this little volume is not intended to be a construction manual and the license examination questions will not be concerned with detailed physical design or mechanical construction details, these subjects are not covered. A great deal of information of this kind will be found in detail in publications devoted exclusively to antennas. In addition, manufacturers of antennas of many types—wire, vertical, and beams—publish a wealth of informative material in the literature advertising their products. A large number of hams prefer to purchase such commercially made antennas rather than face the often rather intricate design and assembly problems involved, particularly in connection with multielement beams.

TRANSMISSION LINES

6-15 In earlier paragraphs and in Fig. 6-1, several methods whereby r-f energy generated by the radio transmitter is transferred to the radiating antenna are shown. Single-wire, two-wire open-line, coaxial cable and twin-lead feedlines have all been discussed. These all come under the general heading of feeders or transmission lines; as such, they comprise a very important part of the antenna system as a whole. In discussing these lines in greater detail, suppose we start with the simple single wire L shown in Figs. 6-1A and B. Actually this is only a continuation of the horizontal wire comprising the antenna itself; it is just as adequate as a radiator. In figuring the overall length of an antenna of this type, it is measured from the far end of the antenna to the point of termination on the transmitter, or coupling unit (discussed later). To this figure must also be added the length of the ground lead from the transmitter to the point of actual entry into the earth. This will represent the overall length of the antennas shown in the illustration. Fig. 6-1A is known as the *inverted-L* type, which Fig. 6-1B would also represent if the lead-in (L) is of appreciable length; otherwise it may be classed as an "end-fed" antenna. In the latter case, the length of L would be included as part of the length of the sloping antenna wire.

6-16 Were the lead-in or feeder to be attached to the exact center of the horizontal span (Fig. 6-1A alternate *a*), the total antenna length would be measured from the transmitter termination to the center of the antenna proper and the distance from the center to either end of the antenna added. Likewise, were the alternate connection made at some convenient random point along the antenna as at alternate *b* in the illustration, the lead-in plus the *longest* portion of the antenna to its insulator would determine the overall electrical length of the antenna. In both of these instances the ground lead should, of course, also be figured in as in the first instance. Actually a lead-in wire such as we have discussed in misnamed when it is referred to as a feeder or transmission line, although it does feed r-f energy to the antenna. It is actually a portion of the antenna itself, when used with random-length wires, and probably the term lead-in is more appropriate.

6-17 A *two*-wire open line, however (*Z* in Figs. 6-1C and F), properly *is* a transmission line or feeder if it is properly constructed and connected with the insulated spacers (*S*) holding the two wires at a precalculated distance apart throughout their length. So arranged, a feeder of this type will theoretically not radiate; it will deliver all of the r-f energy to the horizontal antenna wire which it feeds. The same is true of a coaxial line and the twin-lead shown at *E* in the figure; both are considered to be nonradiating lines.

6-18 Coaxial line, or cable as it is often referred to, is available in several sizes of different impedance values. Those most popular for amateur applications, however, are the types known as *RG-8/U* and *RG-58/U* (of approximately 50 ohms impedance) and *RG-11/U* and *RG-59/U* of about 75 ohms impedance. At the impedances listed, the only difference between the *RG-8/U* and *RG-58/U* is the physical size. The former has an outer diameter of .405″, while the latter is about half that size, being .195″ OD. The same applies to the *RG-11/U* and *RG-59/U*, although the latter, being .242″, is slightly larger than the *RG-58/U*. Actual construction of all these lines is identical in that they have a polyethylene dielectric over the inner conductor, a copper braid over that, and a plastic outer sheath over the entire structure. Electrically, their current-carrying capacity varies somewhat; the two larger cables have seven-strand conductors averaging about the equivalent of No. 16 solid wire. The two smaller lines are of solid wire of No. 20 or No. 22 size. The *RG-8/U* and *RG-59/U* will easily handle any power which the amateur can legally apply to them. Both of the smaller sizes are recommended for use in lower-power applications and with receivers.

6-19 The twin-lead type line is of different construction. Rather than a braided shield as in coaxial line both conductors in the twin lead are identical and are placed parallel with approximately ½″ spacing and molded in this position in a jacket of polyethylene. Two readily available sizes electrically are most popular in the amateur field: 72-ohm and 300-ohm. The flexibility of both coaxial lines and twin lead is often an advantage where they must be run in such fashion as to require numerous bends, or in placing them between walls and in similar circumstances where the use of open-wire lines would be impractical. Both coaxial cable and twin lead have greater losses than the open type line, but the advantages and disadvantages of the various types are fairly well balanced, leaving the choice of a transmission line open.

6-20 With the open two-wire type line of Figs. 6-1C and F, spacing between the wires is, of course, under the control of the constructor. It may be anything which he determines proper for the conditions under which he will operate. Amateur transmission lines of this type have their conductors spaced at anywhere from 2″ to 6″ apart. The exact spacing distance will depend on the surge impedance you wish to present to the transmitter and antenna. This impedance can be calculated by the formula:

$$Z_0 = 276 \log_{10} \frac{2S}{d}$$

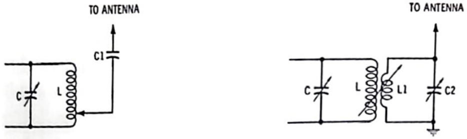
Where,

Z_0 is the surge impedance,
S is the distance between wire centers,
d is the diameter of wire,

Both S and d must be in the same units of measurement. A little radiation from using such lines may be expected, but actually it represents very little loss which may, in most cases, be ignored. A large part of such radiation that may be present is cancelled out by the "free" wire of the two wires comprising the line. This, incidentally, is the function of the second wire, which merely parallels the antenna conductor for its full length, but it is *not* connected to the antenna or for that matter to *anything* conductive at the upper end. It acts therefore merely to balance and cancel the radiation from the "live" conductor. The impedance of this type line varies rather widely within certain limits, the average impedance falling between 300 and 600 ohms.

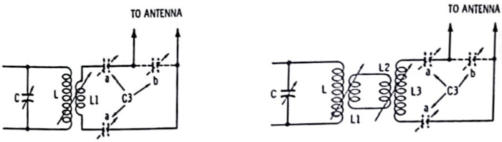
OUTPUT COUPLING METHODS

6-21 The preceding chapters have taken you progressively through the complete circuits of a radio transmitter from the power-supply source up to the antenna; however, there is still one gap to fill in order to realize actual radio-frequency radiation from the antenna. This is the means by which the antenna is connected or *coupled* to the output of the transmitter itself. There are several methods by which this is accomplished. Probably the most simple of all are the *capacitive* method and the *inductive* method. These are both illustrated in Figs. 6-5A and B. In most manufactured kits or transmitters a built-in coupling arrangement, broadly referred to as a *pi network*, provides a satisfactory means of transferrring the radio frequency generated in the transmitter circuit directly into the transmission line or feeder and thence to the antenna proper. Such a method (Fig. 6-5E) is used by a number of manufacturers as well as by many who build their own equipment. Including as it does a "tuning capacitor" and a "loading capacitor," it usually requires no additional external apparatus, and the transmission line may be connected directly to the antenna terminal of the transmitter in most cases. While such an arrangement performs very satisfactorily and is in rather common use, it is possible to achieve a much better impedance match between the transmitter and a transmission line, and between the line and the antenna, through use of an external antenna-coupling device. Such a device is widely used where the utmost in efficient transfer of r-f from transmitter to antenna is desired. Careful adjustment of external tuning devices permits compensating for large amount of reactance to an extent dependent on frequency and the line or antenna resistance. The tuned circuit of the antenna coupler also provides considerable harmonic attenuation of the transmitter output. Impedance matching in the type of antenna coupler shown in Fig. 6-5F is accomplished entirely from the front



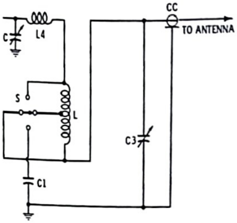
(A) Simple capacitive feed.

(B) Simple inductive feed.



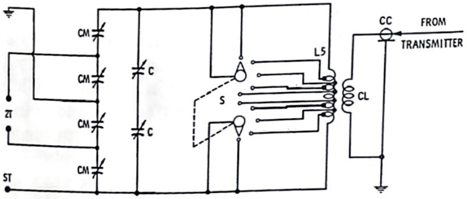
(C) Inductive two-wire feed.

(D) Link-coupled two-wire feed.



(E) CONAR pi-network feed.

Courtesy Conar



Courtesy E. F. Johnson Co.

(F) Johnson Matchbox coupler.

KEY TO SYMBOLS:

C-TUNING CAPACITOR
C1-FIXED MICA CAPACITOR
C2-LOADING CAPACITOR
C3 - a-a OR b LOADING CAPACITORS
(EITHER MAY BE USED)
CC-COAXIAL CABLE CONNECTOR
CL-COUPLING LINK
CM-MATCHING CAPACITORS

2T-TERMINALS FOR 2-WIRE (OR COAX) FEED LINE
ST-TERMINAL FOR SINGLE-WIRE FEED LINE
S-MULTIPOINT SWITCHES FOR BAND CHANGING
L-FINAL AMPLIFIER TANK COIL
L1 and L2 - COUPLING COILS
L3-ANTENNA COUPLING COIL
L4-15-METER TANK COIL
L5-ANTENNA TUNING COIL

Fig. 6-5. Antenna feed systems.

panel of such a device without adjusting coil taps or inductance coupling. In short, the addition of a well-designed antenna coupler is a distinct asset to any transmitter whether or not it is equipped with the "compromise" coupler represented by the built-in pi network.

STANDING WAVES

6-22 The term *standing waves* appears frequently in published material and in vocal discussions. While the effect of standing waves on efficient radiation of r-f power is often overemphasized, they do represent some loss which may be minimized by proper impedance matching between the transmission line and the antenna. They represent *reflected power* in that some of the power reaching the antenna is reflected back down the line and contributes nothing to actual radiation. What proportion of power is so reflected as compared to that appearing on the antenna must be measured, and various types of measuring devices for this purpose are manufactured or may be built by the home constructor from published articles or his own design. The ideal radio-transmission installation cannot be said to be entirely devoid of such standing waves, but as previously mentioned, they can be minimized by proper impedance matching. The acceptable range of standing wave ratio for an amateur station can be said to fall somewhere between about 1.5 to 1 and 5 to 1, the lowest possible figure within this range representing the most desirable. To secure a ratio of 1.5 to 1 is not too difficult at the higher frequencies, but it can be expected to be greater as the frequency is lowered; 5 to 1, however, is about the extreme that should be tolerated for good efficiency at the lower frequencies.

6-23 In the foregoing paragraphs, a bit of history has been given involving the "evolution" of the ham antenna from the early wire types through modern single-band resonant wires, the widely accepted vertical antenna, and finally the fixed and rotary beams. This history has been covered for several reasons: first, the radiating system must be accepted as one of the most vital parts of any radio-transmission installation. Without a well-designed and efficient antenna and its accessory components, the finest transmitter in the world stands a pretty poor chance of competing with even the "peanut whistle" transmitter of the novice using a random-length antenna. Second, the historical background of antenna development should give you a more intelligent idea of what to use for an answer to some antenna question which you may be faced with on your examination sheet. Too, for those who long ago allowed their General-class license to lapse and lost interest in amateur radio for many years but are nevertheless eligible to take the Advanced- and Extra-class examination, it will serve to refresh their memory and to fill in the gaps in their ham experience.

6-24 RADIATING SYSTEM QUESTIONS AND ANSWERS

1. What comprises the most simple antenna to erect and use?

Ans. A single random-length wire suspended above the earth at either or both ends.

2. How may r-f energy be fed to such an antenna?

Ans. By a similar single wire connected to either end of the horizontal span, in the center, or at some random point along its length.

3. What change may be made in the horizontal span to make such an antenna a more effective radiator?

Ans. It can be cut to precalculated length equal to a full, half, quarter, or eighth wavelength.

4. Can a single-wire lead-in, as in question 2, be used with the resonant antenna of question 3?

Ans. Yes, but so connected it remains a random-length antenna, and in calculating the overall electrical length of the horizontal span, the length of the lead-in and ground wire are added so that the total physical stretch of the antenna for a definite frequency is measured from the far end of the antenna, down through the lead-in and on from the transmitter to the ground connection to actual earth.

5. Can a single wire be made to feed an antenna which has a horizontal span cut to full length (full, half, quarter, or eighth wavelength) for the desired frequency at greater efficiency than that of a single-wire random-connected lead-in?

Ans. Yes, by connecting the lead-in to the horizontal span at a point 14% removed from the center (Fig. 6-1D).

6. Name two other methods of effectively feeding rf to a resonant antenna.

Ans. At either end or in the center, using a 2-wire feed line. Such feeder may be of the open-wire, coaxial-cable, or twin-lead type.

7. Describe briefly a vertical radiator.

Ans. A vertical radiator may be a wire hanging vertically from a support; a metallic structure such as a tower; or a length of pipe, rod, tubing, or similar item supported vertically.

8. Is the height of a vertical radiator of consequence?

Ans. Yes, like the resonant wire antenna, it should be of a height to equal a full, half, quarter, or at minimum, an eighth wavelength. Customary amateur practice uses a quarter wave to avoid mechanical problems presented by higher structures.

9. Is a vertical radiator grounded or insulated at the base?

Ans. This is a matter of choice and the radiating qualities of a vertical radiator are effective using either method.

10. What is meant by the "directivity" of an antenna?

Ans. The property to radiate better in some directions than in others. All antennas are directive to varying degrees.

11. Can an antenna of the horizontal-wire type be arranged to be directive in a planned direction?

Ans. Yes, where it is possible to erect the antenna in such a way as to permit its calculated directivity to be in a desired direction.

12. For the most efficient use of such directive effects what type of antenna is generally chosen?

Ans. In the wire-type antenna, the "rhombic" type will produce most directivity. These are, however, seldom used in amateur applications due to the large area which they require. Amateur demand for planned directivity makes the "beam" antenna, either fixed or of the rotatable type, most popular for such use in the frequency bands of 14.0 mc and higher. Physical size limitations discourage the use of such beams on the lower frequencies.

13. With reference to beam antennas, what is meant by the terms "director" and "reflector"?

Ans. A reflector is an element mounted behind the beam-antenna radiating elements to "push" the radiation toward the desired direction. A "director" is a similar element mounted in *front* of the beam to "pull" the radiated energy in the desired direction. The more directors the more narrow the beam width.

14. To what does the term "standing waves" refer?

Ans. Standing waves represent power reflected back down the transmission line from its point of connection to the antenna. Correctly matching the impedance of the antenna and the line will substantially reduce such reflected power which is of no value.

15. What is the generally accepted standing-wave ratio in an amateur radio installation?

Ans. From 1.1 to 1 to 1.5 to 1, in the higher frequency bands. A ratio of as much as 5 to 1.0 may be tolerated on the lower frequencies.

16. How may the output of a transmitter be coupled or fed to an antenna?

Ans. There are several methods (Fig. 6-6). The simplest forms are either the direct capacity feed or the coupled inductive method. Antenna coupling units designed to match impedances are often used. These are made up of inductive and capacitive components arranged in various appropriate circuitry. A modified tuning/coupling arrangement is found in many transmitters wherein the transmitter output tank circuit serves both as the transmitter final-amplifier inductance as well as the antenna coupler (Fig. 6-5E).

17. Are antenna couplers adaptable to any type of antenna and transmission line?

Ans. Yes, they may be so used.

18. Briefly describe a coaxial cable.

Ans. Coaxial cable is composed of two concentric conductors separated by insulating material, usually polyethylene. The inner conductor is of solid or stranded wire; the outer conductor is of copper braid. A neoprene jacket encloses the entire assembly.

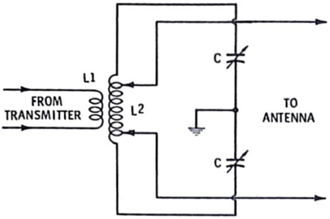
19. What is a two-wire open transmission line?

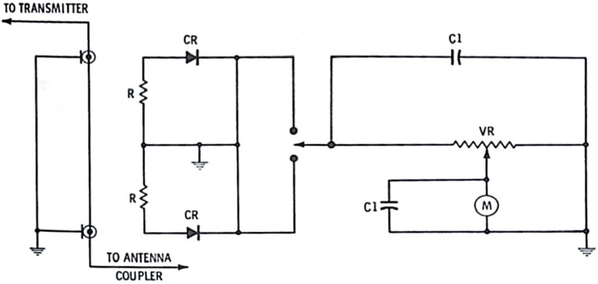
Ans. Two parallel wires feeding the antenna from the transmitter or coupling unit. The wires are separated from each other at spacings varying from 2″ to 6″.

20. Describe a dual parallel line such as "twin-lead."

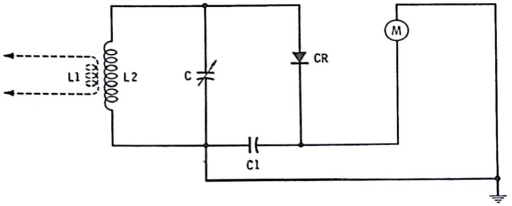
Ans. Two wires are molded in a polyethylene sheath, separated from each other approximately ½″.

(A) Simple antenna coupler.





(B) Directional coupler and SWR indicator.



(C) Simple wavemeter may be used as SWR meter on open-wire or twin-lead lines.

Courtesy E. F. Johnson Co.

KEY TO SYMBOLS:

C- TUNING CAPACITOR
C1- BYPASS CAPACITOR
L1- COUPLING COIL
L2- TUNING INDUCTANCE
R- FIXED RESISTOR

VR- VARIABLE RESISTOR
CR- CRYSTAL DIODE
M- 0 TO 100 ma METER
S- 2-POSITION SWITCH

Fig. 6-6. Coupling and SWR devices.

21. How may standing waves be measured?

Ans. By a 0- to 1-ma or other low-reading d-c meter with appropriate circuitry. This is coupled to the line and if the meter has been precalibrated, the standing-wave ratio or "SWR" can be read directly. A bridge type SWR indicator must be used with coaxial cable.

22. Which represents the most desirable SWR: a ratio of 1.5 to 1 or 5 to 1?

Ans. The lower reading; i.e., 1.5 to 1.

23. In using an open two-wire transmission line feeding a single-wire antenna at one end, one wire is connected directly to the antenna. To what is the upper end of the other wire connected?

Ans. It is left electrically unconnected at the upper end.

24. When is the ground lead from a radio transmitter considered as a part of the antenna length?

Ans. When a random length antenna with a radiating wire lead-in is used.

25. Is the lead-in wire also considered in figuring the antenna length when using a random-length type of antenna?

Ans. Yes, the length of the lead-in should be added to the horizontal electrical length of the antenna.

CHAPTER 7

Modulation

7-1 In the preceding chapters the makeup and operating characteristics of a radio-frequency generating system from the initial primary-power source, through the various stages, to the actual radiation of a pure continuous wave from an antenna system have been discussed. Such radio-frequency radiation, when broken into the characters of the radiotelegraph code through various methods of keying, constitutes a complete c-w, or continuous-wave, radiotelegraph transmitting station. That, however, is *all* that it provides. Transmission by radio of the human voice, music, various steady tones, and other aural expressions is something else again. Early experiments with the transmission of sounds by normal means were limited to what could be done on a telephone line, for example, where the connecting wires between two points served as the *carrier* for the audio frequency generated by a microphone. To accomplish the same thing *without* connecting wires to carry the various audio frequencies which make up intelligent communication was the problem presented in attempting to create a means of audio transmission through the use of radio-frequency waves.

During the pioneer days when radiotelegraph communication was all accomplished by the spark method of r-f generation, the problems presented in attempting to introduce audio frequency into the r-f circuits were found to be insurmountable, and efforts along these lines were soon abandoned. With the later development of radiotelegraphy by means of r-f waves generated by an arc between two carbons or a carbon and a metallic electrode, some renewed but rather half-hearted efforts were put forth to impress audio frequencies on the already existent radio-frequency output. A small measure of success was achieved first by talking directly into the flame of the arc. This produced sounds in a receiver which bore a faint resemblance to the human voice, but which were barely understandable. Following these elementary experiments, a carbon telephone-type microphone was placed in series with the ground lead of the transmitter. The voice was slightly more intelligible while the microphone lasted, but the carbon granules in the mike soon packed, rendering it useless. Next, a microphone and battery in series with a coil of a few turns was tightly coupled to the tuning inductance of the transmitter. This method resulted in still more improvement, but the voice at the receiving end was hollow and sepulchral, and a speaker could not be identified from his voice inflections. Better results were later secured with both the arc and the high-frequency alternator methods of generating rf, but the commercial practicality of the radiotelephone remained rather doubtful, although it was used for a time.

With the invention and development of the vacuum tube and the discovery of its great versatility, radio transmission of the human voice, music, and other sounds came into practical use. Today, radiotelephony is as commonly accepted as the land-line telephone, the electric light, and the automobile.

7-2 The radio amateur was quick to take advantage of this new field in which to experiment and communicate. Many of the earliest pioneers in the development of the radiophone were themselves radio hams and experimenters, and their ranks grew by leaps and bounds. As the pure continuous-wave generation of vacuum-tube transmitters became known, various methods of modulating the r-f carrier were tried, discarded, and approached from different angles. Problems arose in this field, but with the hundreds of experimenters seriously working for solutions, they were solved almost at their inception. The final result has been to give us today amateur radiotelephone communication much of which is as high in quality and fidelity as that of the better broadcast stations.

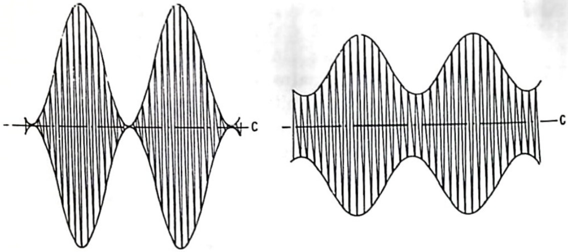
THE AUDIO SYSTEM

7-3 This is termed a *system* since there is more involved in radiotelephone circuits than just a vacuum tube and its connecting wires. There are many methods and means of modulating an r-f signal. The terms *amplitude* and *frequency* modulation (am and fm); grid, plate, screen, and cathode modulation, single-sideband; and others are frequently heard. Amateur radio is concerned first with amplitude modulation which ranks first in popularity and general use although the single-sideband system is rapidly pushing to the fore.

7-4 Regardless of which modulation system is used, it must be remembered that the modulating frequency, which is superimposed on the radio-frequency carrier, is an *audio* frequency. As such, it cannot be transmitted through space by itself. It *must* have the r-f carrier on which to ride. Therefore the audio modulating frequency must combine with the radio frequency in the transmitter in order to transmit audio signals to a receiving station. Accordingly, through additional components and circuitry in the transmitter, the audio circuit output is mixed with the r-f output which serves to combine the two so that they "ride together" to the distant receiver.

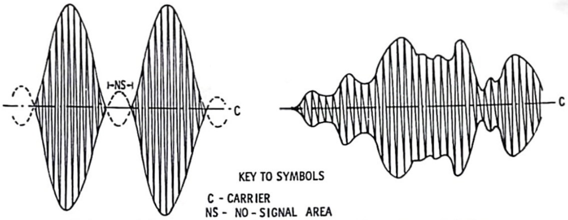
7-5 While the carrier remains at a fixed level determined by the r-f output of the transmitter, the process of modulation creates additional frequencies known as *sidebands* which appear both above and below the carrier frequency. Those above the carrier frequency are referred to as *upper sidebands* and those below as the *lower sidebands*. The amplitude of the modulated wave is varied, depending on the amount of audio signal superimposed on the carrier frequency. At 100% modulation (accepted as the theoretically perfect value), a 50% power increase in the modulated signal will result, 25% being in each of the two sidebands. To modulate an r-f carrier at a value greater than 100% will result in the generation of spurious radiations by reason of the increase in frequencies produced by such *overmodulation*. The reception of such an overmodulated signal will also be distorted at the receiving point. An *undermodulated* carrier will result in less signal strength at the receiver, although distortion will not be present. Theoretical perfection, or 100% modulation, is the legal upper limit permitted by existing FCC regulations, just as the *radio* frequencies for amateur use are limited by law to definite *bands*. R-f carrier transmission is permitted anywhere within the band limits and, of course, within the terms of the operator's license. Likewise, modulation percentages *below* 100% are perfectly legal. Many amateurs choose to modulate somewhere between 90 and 95% to ensure remaining within lawful limits; such a percentage value is adequate for the modulating range of the human voice. High-fidelity broadcast stations on the other hand will approach 100% modulation very closely. They have many more audio frequencies to deal with, particularly in the musical range, and they are equipped with precision measuring equipment to maintain their modulation percentage within very close limits; such equipment is generally beyond the economic reach of the ham.

7-6 Fig. 7-1A illustrates 100% modulation by a steady audio tone, such as 5 kc for example. The sidebands produced by this tone will be 5 kc above and 5 kc below the carrier frequency. If the latter is 3950 kc, the upper-sideband frequency will be 3955 kc; the lower sideband will be 3945 kc. This spread



(A) 100% amplitude modulation.

(B) 50% amplitude modulation.



(C) Overmodulation.

(D) Voice modulation.

Fig. 7-1. Specimen modulation patterns.

would create a *bandwidth* of 10 kc, which is considerably more than is required for amateur radiotelephone operation. An arbitrary value generally acceptable is a bandwidth of about 6 kc divided equally between the upper and lower sidebands. This will result in excellent speech and confine the bandwidth to a reasonable spread. Three stations could operate simultaneously separated by 6 kc each without overlapping, occupying as they would a total of 18 kc. On the other hand, with a bandwidth of 10 kc, only *two* stations could operate within the same band spread, and they would be pushing their luck a bit at that with some slight overlapping. In Fig. 7-1B, a 50%-modulated signal is shown graphically using the same steady audio tone. Fig. 7-1C shows an overmodulated wave. Note that it exceeds 100% on peaks and that at the minimum point it drops *below* the carrier. During the short interval before it again returns to the carrier level, radiation of the modulated wave ceases, resulting in distortion at the receiver. Fig. 7-1D illustrates a signal modulated by the human voice at about 95% modulation, which represents an excellent value for amateur operation.

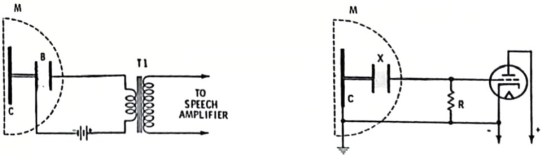
MICROPHONES

7-7 Modulation rightly commences at the *microphone*, a device for converting aural sounds such as voice, music, and similar sounds into variations of an electrical current. There is a variety of microphone types used in radiotelephony, the most simple being that of the *carbon* type. This consists of a cup of insulating material in which carbon granules are lightly packed and a metallic diaphragm is arranged to contact the carbon granules. As sound waves strike the diaphragm, it follows the variations of the sound, thus causing changes in the electrical value in the microphone circuit. Since the output of such a microphone is relatively weak, it is, except in very low-level modulation, fed into the input of a speech-amplifier transformer in series with a small amount of direct current obtained either from a battery or from the cathode circuit of the speech-amplifier tube. The term "low-level" is used to designate modulation which is fed to one of the lower-power amplifier stages of the transmitter; "high-level" is the term applied where the modulation takes place in the transmitter stage of highest output, i.e., the final amplifier. Carbon microphones are rarely used in the fixed amateur station (particularly those stations of any power) but are often found in the relatively low-powered portable and mobile amateur stations.

7-8 The *dynamic-type* microphone is popular in a great many amateur stations. This resembles, in a small way, the speaker-microphone used in most intercom equipment. A voice coil and diaphragm similar to a cone-type speaker (although physically much smaller) are used, and the voice coil is placed in the field of a permanent magnet. Sound reaching the diaphragm (or what would be the cone in a speaker) causes the voice coil to move in the magnetic field, thereby generating a varying alternating current, which is fed to the input of the speech amplifier. In contrast to the carbon microphone, which requires a microphone transformer, the output of the dynamic microphone is fed directly to the grid of the speech-amplifier tube. Often a low-powered preamplifier is used to receive the weak output of the microphone and amplify it somewhat before passing it on to the speech amplifier. The dynamic microphone has excellent audio-frequency response over a wide range of frequencies—hence its popularity. Unlike the carbon microphone, no external voltage is required to activate the dynamic type; it generates its own voltage as explained above.

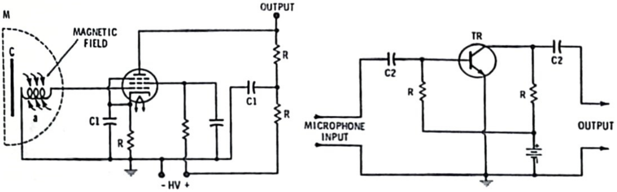
7-9 Another type of microphone held in high favor by the amateur is the *crystal* microphone. Rochelle salt forms the crystal element; and the crystal microphone requires no battery or other external voltage source. Its output may, like the dynamic mike, feed directly into the grid of the speech amplifier or preamplifier tube. The frequency response of this microphone is adequate for amateur operation, and the crystal microphone may be had at reasonable cost. Figs. 7-2A, B, and C schematically illustrate the three microphones described. In Figs. 7-2D and E are shown preamplifier and speech-amplifier circuits which may be used with these microphones.

7-10 The audio output from the speech amplifier is projected to the modulator, from which stage it enters into the r-f circuits in the transmitter. This may be through a variety of methods: plate, grid, cathode, screen grid, and others. All represent amplitude modulation wherein the impressed audio frequencies serve to control the amplitude of a radio frequency. All of the modulation methods described are in use throughout



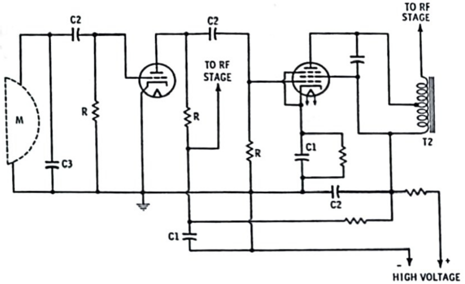
(A) Simple transformer-coupled carbon microphone.

(B) Crystal microphone resistance-coupled to speech amplifier.



(C) Dynamic microphone and pentode speech amplifier.

(D) Transistor preamplifier.



(E) Microphone and speech amplifier resistance-coupled to a pentode modulator.

KEY TO SYMBOLS

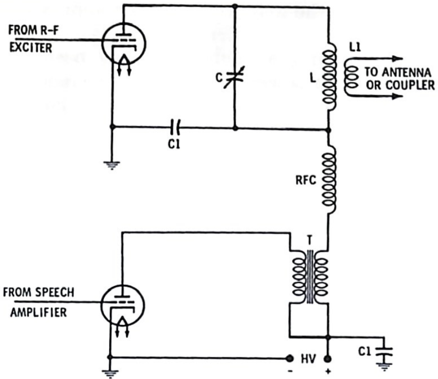
C - DIAPHRAGM.
b - CARBON GRANULES.
T1 - MICROPHONE TRANSFORMER.
X - QUARTZ CRYSTAL.
M - MICROPHONE.
R - RESISTOR.
C1 - BYPASS CAPACITORS.
C2 - BLOCKING CAPACITORS.
C3 - FREQUENCY-RESPONSE CAPACITOR.
T2 - MODULATION STEP-UP AUTOTRANSFORMER.

Fig. 7-2. Modulation configurations.

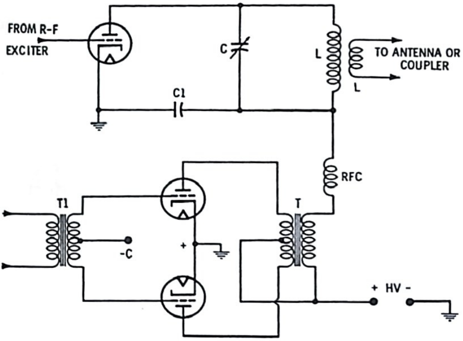
the amateur field, but the plate system of amplitude modulation leads in popularity. Plate modulation simply adds the sidebands created by the audio frequencies to the radio-frequency carrier, and the two combine to increase the power of the radio-frequency wave picked up by the distant receiver. A typical modulator using this system to modulate a triode radio-frequency amplifier is shown in Fig. 7-3A. The single-triode tube modulator, as shown, is operated as a class-A amplifier. This is not the most desirable method of amplification, because such a stage, operating class A, has poor efficiency, since the tube is conductive for the entire cycle of the input signal. This results in continuous dissipation of heat by the plate and it is, therefore, impossible to take full advantage of maximum power output.

7-11 While the single-tube modulator shown in Fig. 7-3A is admittedly inefficient, it nevertheless enjoys a certain measure of popularity among the low-power advocates as well as in both portable and mobile applications. The *push-pull* type modulator, using two tubes, illustrated in Fig. 7-3B, and working into a neutralized triode r-f amplifier, is considerably more effective. The push-pull arrangement shown can be used as either a class-A or a class-B modulator stage. Push-pull operation will also result in greater power output. Class A is the more preferred method inasmuch as it requires much less driving power from the preceding speech amplifier and is capable of distortion-free output. Class B requires greater driving power and introduces a small degree of distortion into the radiated signal.

7-12 We have in the foregoing paragraph, mentioned only two classes of modulator, classes A and B. Classes AB_1 and AB_2 are also popular in amateur use. Class-AB amplifiers, as the term would indicate, represent a combination of both the class-A and the class-B types, taking advantage of the desirable characteristics of each. Such an amplifier embraces the low-distortion capability of the class-A type as well as the greater power output of the class-B amplifiers. A class-A amplifier can be used either as a voltage or a power amplifier. The grid bias and a-c voltage applied to the grid of a tube operating in class A are such that plate current flows through the tube at all times with or without an applied signal. A class-B amplifier is biased approximately to cutoff value (the point where the plate current is practically zero) and conducts when



(A) Single triode modulating the final r-f amplifier.



(B) Push-pull triodes modulating a triode final amplifier.

KEY TO SYMBOLS

C - TUNING CAPACITOR.
L - TUNING INDUCTANCE.
L1 - OUTPUT COUPLING COIL.
RFC - RADIO-FREQUENCY CHOKE.

T - MODULATION TRANSFORMER.
T1 - AUDIO-INPUT TA
T1 - AUDIO-INPUT TRANSFORMER
-C - BIAS SUPPLY SOURCE.

Fig. 7-3. Single-end and push-pull modulation.

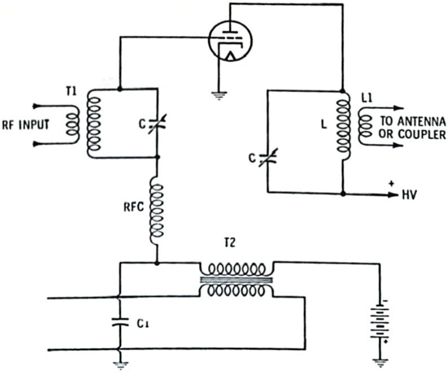
a signal is applied to the grid, but only for approximately half of each cycle.

7-13 Thus far only plate modulation has been dealt with. This requires an audio power output from the modulator equal to about one half the input power to the modulated r-f stage. This sometimes becomes somewhat costly, particularly in transmitters in the medium- and high-power classifications. Accordingly, many hams resort to *low-level* modulation, which is accomplished in one of the lower-powered r-f amplifier stages of the transmitter, or they adopt the *grid*-modulation method. Low-level modulation, while frequently used, is not the most popular method. If a stage below the final r-f amplifier is modulated, all following stages are operated as class-A amplifiers, which will amplify and deliver the signal to the radiating system without distortion. Were class-C amplification to be used, distortion of the r-f output signal would result. Grid modulation, on the other hand, offers a relatively simple and economical method of modulation of the final amplifier, as is evident from Fig. 7-4A. Grid modulation will not, however, produce nearly as much modulated-carrier power as a similar plate-modulated transmitter. The carrier power could be reduced as much as 75% through the use of grid modulation. One advantage is significant though; grid modulation requires very little audio power, substantially reducing the cost of modulation components. An audio amplifier for grid modulation must be of the class-A type, otherwise distortion of the radiated wave will result. Where low-cost modulation for a low- or medium-power transmitter is the goal, grid modulation finds its place.

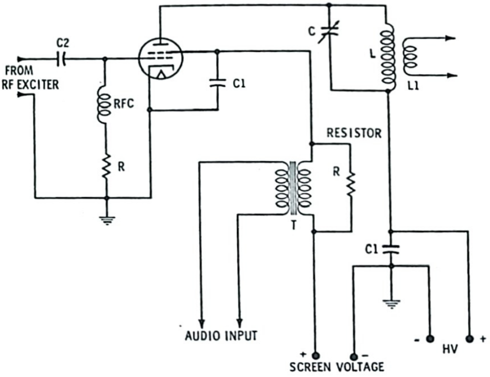
7-14 A number of other modulation systems are in use, none of which equals the popularity of the plate and grid methods just described. Suppressor-grid, cathode, and screen modulation are commonly used. The very latest development, single-sideband modulation, is rapidly gaining increasing favor in the amateur ranks.

Pentode tubes can be modulated rather well with the audio output of the modulator feeding directly into the suppressor grid. This grid must be biased for such operation, although the actual value (which will average about 100 volts negative) is dependent on the particular type of pentode tube employed.

Cathode modulation represents a combination of both plate- and grid-modulation methods. While its efficiency is not as



(A) Control-grid modulation.



(B) Screen-grid modulation of a tetrode.

KEY TO SYMBOLS

T1 - INDUCTIVE COUPLING FROM R-F DRIVER TO FINAL R-F AMPLIFIER.
C - TUNING CAPACITOR.
C2 - BLOCKING CAPACITOR.
C1 - BYPASS CAPACITORS.
R - RESISTOR.
RFC- RADIO-FREQUENCY CHOKE.
T - MODULATION TRANSFORMER.
L - TUNING INDUCTANCE.
L1 - R-F COUPLING INDUCTANCE

Fig. 7-4. Grid and screen-grid modulation systems.

high as that of pure plate modulation, it does exceed the efficiency of grid modulation appreciably and finds rather wide usage in the low-power transmitter field.

Screen-grid modulation, another method which has met with better than fair acceptance, feeds the screen of the r-f tube through the modulation transformer. Screen modulation has the added advantage of simplicity both in application and adjustment; this method is of course adaptable to modulation of either tetrode or pentode tubes in the final r-f amplifier.

7-15 While much has been written and continues to currently appear in almost all of the national electronic periodicals as well as in various handbooks covering single-sideband radiotelephony, much of such information has been based on construction practice as well as theoretical analysis. This is understandable when it is considered that this transmission method has come into popular favor only in relatively recent years; and, proven though it is, a great deal of experimentation with this system of radiotelephony is still being pursued. Basically, it is not at all difficult to understand. One of the narrow bands of frequencies created on both sides of the carrier is used to carry the modulated signal. The other sideband is eliminated, and the "spread" of the modulated transmission is cut a theoretical 50%. Naturally this then makes room for an additional station to operate simultaneously, while removed only a few kilocycles (3 kc rather than 6 in the case of am, for example) from the carrier frequency. In this mode, not only the unwanted sideband is eliminated, but the carrier itself is suppressed either through a *balanced-modulator* circuit arrangement or through the use of a *mechanical filter* and balanced-modulator combination.

Without a carrier, a meaningless jumble of sound results in the average communication receiver adjusted for radiotelephone reception. Nevertheless, such a receiver, if equipped with a beat-frequency oscillator, *can* receive perfectly intelligible single-sideband transmission by artificially *restoring* the carrier at the receiver. Operating the receiver in an oscillating condition which in effect generates sufficient carrier to replace that suppressed at the distant transmitter, coupled with careful tuning, will bring clear and perfectly intelligible single-sideband transmissions into your phones or speaker.

7-16 In this chapter the essentials of modulation to the extent which you are likely to encounter them in the Advanced-

or Extra-class examination have been covered. Remember that if you now hold a General ar Advanced class of license, and are attempting the Extra-class exam, all of these elements will be waived and you will be required to take only elements 1(C), 3, and 4(B). [If you now hold a General-class license, element 4(A) must also be taken.] These may also be waived in their entirety if you qualify and are applying for an Extra-class license under the provisions of the "Grandfather" clause (Chapter 1, paragraph 1-9). You should also know what the waiver of examination element 1(B), 2, and 3 will not be allowed to holders of Novice-, Technician-, or Conditional-class licenses, valid or not. Such licensees *must* take the entire list of elements required for the license they are applying for.

7-17 If after considering the examination elements and certain waivers involved, you determine that your General- or Advanced-class license being valid entitles you to waive elements 1(B), 2, 3, and 4(A), your first question will probably be, "Why do I have to study the preceding chapters dealing with these elements? I passed them once already!" So you did, but how long ago? Maybe 5, 10, perhaps 15 years ago, and each time your license reached expiration date, you simply renewed it *without* examination of any kind. If your interests since then have been mainly in the operational rather than the technical field of amateur radio, you are probably stale on many points which you took in stride originally. Study *all* of the chapters in this book and make sure that you know what current ham practice is all about.

7-18 MODULATION QUESTIONS

1. What is the maximum legal modulation percentage which an amateur radio station may use?

Ans. 100%.

2. If a signal is modulated at *greater* than 100%, what is it termed?

Ans. Overmodulation.

3. What effect does radiation on an overmodulated signal produce?

Ans. Distorted reception at the receiving point; creation of excessively wide sidebands causing "splatter" or unnecessary interference with transmissions from other stations.

4. Name any effects produced by undermodulation.

Ans. Slight undermodulation is desirable to avoid possibility of overmodulation and is not noticeable at the receiving point. Too extreme undermodulation will result in weaker signals at the receiver but they will arrive undistorted.

5. What is the average acceptable "bandwidth" of a modulated signal?

Ans. Approximately 6 kc divided equally on each side of the carrier frequency.

6. Describe briefly the construction of a carbon microphone.

Ans. A carbon microphone is composed of a housing containing a small "cup" in which carbon granules have been inserted. A diaphragm is arranged to make contact with such granules at a pressure determined by the fluctuations of the human voice or other aural sounds. This varies the resistance of the carbon granules causing a variation of the voltage in the microphone circuit.

7. How does a dynamic microphone differ from the carbon type?

Ans. A dynamic microphone is somewhat similar to a receiving speaker. A voice coil is attached to a diaphragm simulating a speaker cone and such coil is arranged to be within the influence of a permanent magnetic field. As sound waves are impressed on the diaphragm, mechanical movement takes place which serves to generate electrical energy in the circuit by the moving coil undulating in the magnetic field.

8. What is a preamplifier?

Ans. A low-powered amplifier which receives the relatively weak output from a microphone and delivers it at a greater value to the input of a speech amplifier.

9. To what is the output from a speech amplifier connected?

Ans. Generally directly into the modulator stage; sometimes through an additional speech amplifier in higher-powered installations of the plate-modulated type.

10. Describe a crystal microphone.

Ans. A diaphragm is arranged to mechanically agitate a crystal element usually composed of Rochelle salts. This acts in a similar fashion to the quartz crystal of an r-f crystal oscillator, inasmuch as mechanical movement of the Rochelle salts generates electrical energy in the microphone circuit in a manner similar to that of the quartz r-f crystal when agitated by an application of electrical energy.

11. Show by simple schematic diagram, circuits for carbon, crystal, and dynamic microphones.

Ans. Use Fig. 7-2A for this answer.

12. Show by a simple schematic diagram a speech amplifier of the transistor type.

Ans. Use Fig. 7-2D.

13. Draw a simple schematic diagram of a speech amplifier using a pentode tube actuated by a dynamic microphone.

Ans. Use Fig. 7-2C.

14. What is the purpose of a speech amplifier?

Ans. To receive the relatively weak output of a microphone or a preamplifier and build it up sufficiently to actuate the modulator circuit of a transmitter.

15. To what does the term "plate modulation" apply?

Ans. A method of modulation whereby the radiated sidebands created by the audio frequency are added to the r-f carrier, the two combining to increase the power of the radiated signal.

16. Show by a simple schematic a triode r-f tube plate-modulated by a triode-tube modulation stage.

Ans. Use Fig. 7-3A.

17. What is one disadvantage of a class-A modulator stage?

Ans. In a class-A stage the tube is conductive for the entire cycle of the input signal, resulting in continuous dissipation of heat by the plate, making it impossible to take full advantage of maximum power output.

18. What advantage has a push-pull modulator stage over one of the single-ended type?

Ans. Push-pull operation using two tubes will result in greater power output. If used as class A it requires much less power input than class B and will deliver distortion-free output.

19. What is grid modulation?

Ans. A method whereby the output of the modulator stage is fed into the control grid of an r-f amplifier. It need have only a low power-output level, making it economical in component cost, but it will deliver substantially less power to the radiated wave.

20. Name several other modulation methods.

Ans. Suppressor-grid, screen-grid, cathode, and single-sideband modulation.

21. What is meant by single-sideband modulation?

Ans. A method whereby the carrier and one sideband are eliminated at the transmitter thereby reducing the bandwidth of the radiated signal. For legible reception, the carrier must be reintroduced through certain techniques at the receiving point.

22. How is the carrier suppressed in single-sideband modulation?

Ans. Through use of a balanced modulator circuit, with or without a mechanical filter.

23. In plate modulation, how much audio power is required?

Ans. The audio power introduced into the plate circuit of the r-f amplifier tube must be approximately 50% of the power input to the plate of the r-f tube to realize 100% modulation.

24. Show by schematic diagram a circuit for modulating the control grid of an r-f stage.

Ans. Use Fig. 7-4A.

CHAPTER 8

Advanced Electrical Principles

8-1 Examination elements 1(B), 2, and 3 have been covered in the foregoing chapters. You are now ready to enter into a more advanced treatment of amateur radio practice as required by element 4(B). The handling of this portion of the examination requirements will be somewhat different from that of the earlier chapters. A more expansive series of questions will be used, with a minimum of explanatory text material. A portion of the sample questions will, as in the actual examination, deal with formulas and equations concerning the elementary mathematics of radiocommunication. If you have been a good mathematics student in high school or better yet have majored in this subject in college you should have no trouble with the relatively simple mathematics required in the examination. If this happens to be a weak subject for you, memorizing the formulas shown and working a number of problems with their aid will familiarize you sufficiently with the examination requirements to enable you to answer the formal questions with little difficulty.

8-2 This advanced material is divided into three general classifications: electrical principles, radio-frequency theory and practice, and audio-frequency theory and application. Using this format will enable you to proceed progressively from the primary source of power for radio operation through the various radio-frequency circuits and finally into the modulation section. In other words, you need not "jump around" from page to page to dig out something which should be lumped under a general heading. From time to time you will be referred back to a preceding chapter in order to avoid repetition, but it will be in connection with subjects with which you should already be familiar if you have thoroughly studied the preceding chapters. Concentration of your study in one section at a time will prove most beneficial to you; do not attempt to absorb a few pages of electrical principles, then jump to a portion of the audio section, and leave that from time to time to delve into parts of the radio-frequency discussion. Be consistent; thoroughly study the electrical section until, in your own mind, you have it down "pat." When you are satisfied with that, take up the radio-frequency section and master all that it contains. Finally, when you complete the audio portion, you should have a pretty fair chance of making the grade in the formal examination if you have been really conscientious in your study. There is, of course, no reason why you should not initially examine *all* portions of the presentation so that you can gain some idea of what to expect as you progress. In fact, you would be wise to do so, but remember to *concentrate* your serious study on *one* section at a time until you have thoroughly mastered it. This is the methodical approach which educators recommend as the means to attain the greatest amount of knowledge with the least expenditure of time. You understand, of course, that the sample questions which are offered cannot, for obvious reasons, be the exact counterpart of those you will receive in the formal FCC examination. They do, however, closely parallel the actual questions, and those which are used with brief answers and explanatory text should enable you to easily recognize and answer those which may appear in your formal examination session at an FCC office. With the exception of certain diagrams which you may be called on to draw, as well as perhaps a few formulas, by far the greater part of the examination will be of the "multiple-answer" type wherein you are given five possible answers to each question from which to choose. You will merely be required to indicate by plainly marking on your answer sheet the answer which you believe to be correct. The multiple-choice type question presents an obvious advantage in that four out of the five possible answers will be incorrect; these you should be able to readily identify, and they often provide you with a clue to the correct answer if you have thoroughly studied all of the material in this handbook.

8-3 The initial source of power for the operation of a radio transmitter can be assumed to be the normal electrical supply to homes, offices, and similar quarters—115/120 volts of 60-cps alternating current. This ac is fed into the various components of a so-called "power supply" through a transformer, such power supply representing a group of electrical devices by means of which the commercial a-c power source is changed into a theoretically pure direct current at voltages both higher and lower than that of the initial a-c supply. When a power supply is broken down into its constituent parts, it is found that the first component in line is the power transformer, which, when its primary winding is energized, produces various higher and lower voltages in the secondary windings.

8-4 In the answers to questions 1 and 2 at the end of Chapter 3, it was shown that every transformer is subject to two losses, both of which represent a waste of power. These were defined as "eddy-current" loss and "hysteresis" loss. Make sure that you understand these two terms and can define them; if they do not appear as questions in element 2, they are very likely to appear among the element 4(B) questions; study them again and be prepared. These two, however, do not represent *all* of the losses to which transformers are inherently subject. In addition, what is commonly referred to as *copper loss* is present. This loss has to do with the windings of copper wire placed around the legs of the transformer core. Wire of any kind used in electrical circuits has a definite value of resistance to the flow of electrical current. This resistance value is dependent on three factors: the material of which the wire is made, the size of its cross-section, and its total length. In transformer construction, copper, being the most economical material of high conductivity (least resistance), is the material from which the wire is fabricated. Its size in *circular mils* is, for most practical electrical applications, reduced to a system of numbers, each representing the cross-sectional size of the wire. Such numbering is based on the *American Wire Gauge*, or *AWG*, standard in the United States; this was formerly known as the *Browne and Sharpe (B&S)* wire gauge. The largest *numbers* represent the smallest *size*. For example, two popular sizes of wire used in radio work are No. 12 (antenna wire) and No. 22 (hookup wire). By the AWG gauge, No. 12 is the larger of the two, and No. 22 the smaller. There are intermediate sizes such as numbers 14, 16, 18, 20, and so on; even numbers are most frequently used for denoting size. The size of wire selected for any particular radio or electrical application is determined first by the amount of current it must easily carry. The factor of voltage does not enter into the calculation of the size of the wire itself; the amount of voltage placed on a wire establishes the size and type of *insulation* with which it must be covered, unless it is to be used in applications such as radio-frequency inductances, which usually call for bare wire.

8-5 Knowing the current to be passed through a copper wire enables determination of the proper size to present the least resistance per foot. *All* wire presents electrical resistance to an extent which varies with the material from which it is made, its AWG size and the overall physical length of the wire through which the current must pass. Obviously if the proper size wire (this is often limited by physical considerations as well as current-carrying ability) must, as in a high-voltage transformer secondary, be several thousand feet in length wound over an iron core, its resistance will be appreciable. A length of perhaps only 100 feet of larger wire, as for a low-voltage filament winding, will present negligible resistance. Resistance then covers the third loss in a transformer and represents what we refer to as the copper loss. Suppose, for example, that you should receive an examination question similar to the following:

Q. What, in a transformer, is known as "copper loss"?

Ans. a. That loss induced in the transformer core by the windings.

b. The heat generated in the windings by electrical flow.*

c. The resistance of the windings to electrical current flow.

d. The value of the voltage which the wire must carry.

e. The current-carrying capacity of the wire.

Obviously, "c" would be the correct answer to mark.

---

* Heating of a transformer, which would also constitute a loss, can be contributed by the windings when the transformer is operated in an overloaded condition. In a properly designed and constructed transformer operated within its factory-established ratings, the generation of heat in the windings is a negligible factor.

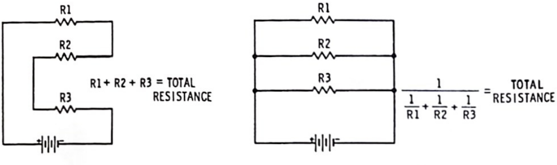
8-6 The discussion of resistance in relation to transformer copper loss in the foregoing paragraph logically leads to consideration of resistance in general, wherever it may appear in an electrical circuit. The element of resistance is often deliberately introduced into radio and electrical circuits to produce definite desired results. For example, if it is desired to lower an existing voltage, placing a resistance element in series in the circuit will accomplish this. Providing an artificial "load" on a circuit such as that represented by a bleeder resistor again deliberately brings resistance into play. Resistors are commercially available for many purposes; they come in various resistance values rated in *ohms*, and in various sizes and materials which determine the current-handling ability in *watts* or fractions thereof.

Those used in radio applications are most generally of two types, the *carbon* and the *wirewound*. Carbon is a poor conductor, presenting a large amount of resistance to electrical flow, but it is not capable of handling very large values of current unless it is of unwieldy physical size. Consequently, carbon resistors are ordinarily used in low-current demand applications, and they seldom exceed 25 watts capacity. For the greater current demands, the wirewound types are universally used. A type of high-resistance wire is deliberately chosen, and one of a calculated size and length to provide the desired resistance and current-carrying capacity is wound on a ceramic core. A coating of baked-on vitreous enamel is applied overall. Some resistors of this type have a narrow path in the enamel coating left bare, and adjustable sliders are arranged to contact this bare portion, permitting adjustment of the resistance to any value desired within its overall resistance value. Where resistors of a required value are not readily at hand, two or more may be placed in series and become additive to provide a higher resistance. Parallel connection of two or more resistors is also often used to provide increased current-carrying capacity and to lower the overall value of the circuit resistance. Both series and parallel arrangements are shown in Fig. 8-1, as is a combination of both, known as *series-parallel*. If resistors of unlike value are paralleled, the total circuit current will be proportionately divided among them but will, at the output end of the resistor bank, total the same as the current value applied to the input. Resistors of like resistance value, if paralleled, will divide the circuit current evenly among themselves. Questions with respect to resistors could possibly appear in your examination.

1. A current of 100 ma is applied to a bank of parallel resistors of different values. What is the resultant current after passing through the bank?

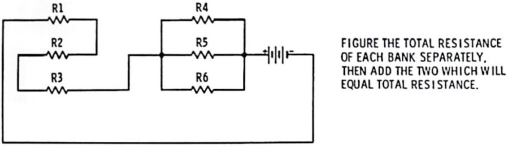
Ans. The same as at the input to the bank, 100 ma.

2. How is the input voltage affected by passing through such a bank?


R1
R2
R3
R1 + R2 + R3 = TOTAL RESISTANCE
R1
R2
R3
$\frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}$ = TOTAL RESISTANCE

(A) Series resistors.

(B) Parallel resistors.


R1
R2
R3
R4
R5
R6
FIGURE THE TOTAL RESISTANCE OF EACH BANK SEPARATELY, THEN ADD THE TWO WHICH WILL EQUAL TOTAL RESISTANCE.

(C) Series-parallel resistors.

Fig. 8-1. Calculating resistance.

Ans. It will be less, the value being determined by the total amount of resistance which the bank presents.

3. How is the input voltage to a series string of resistors affected by passing through such a string?

Ans. The voltage will be lower at the output in proportion to the added values of each individual resistor.

4. In a circuit in which 2000 volts are flowing at 250 ma, what is the circuit resistance?

Ans. 8000 ohms.

5. How did you arrive at this value?

Ans. By the application of Ohm's law, wherein $R = \frac{E}{I}$.

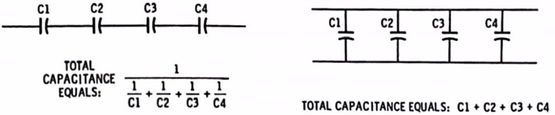
Use the formulas of Fig. 8-1 and work out a number of hypothetical problems of your own to familiarize yourself with the processes.

8-7 The resistors just discussed represent both the fixed and the adjustable type. In addition to these, resistors of a continuously variable rotary-arm type, generally of low wattage, find frequent use throughout radio circuits. They serve as volume controls in receivers, audio-gain controls in modulation systems, keyer-tube adjustments, grid-drive variation, and many other similar applications. These too are either of a carbon or wirewound type. In the former, a carbonized strip of insulating material is housed in a small circular container arranged with an arm that moves over the carbonized surface when it is actuated by a shaft which is readliy available for manual adjustment. The wirewound type is of similar construction, but highly resistant wire is wound on an insulating strip rather than carbonizing such a strip. Both are indicated schematically in the same manner wherever continuously variable resistors are called for in a circuit. Just remember that there are really three distinct types of resistors: the fixed, the adjustable, and the continuously variable. All of these types will be found (either of carbon or wirewound) in practically all radio circuits.

8-8 The next electrical element to be encountered in connection with a power-supply system is the rectifier, which may be of either a vacuum- or mercury-vapor-tube type or the more recently introduced mineral diodes. While tubes are generally thought of in radio- and audio-frequency applications, those in a power supply are distinctly not in either category, but serve a purely *electrical* purpose. Their function is to "rectify," or change, the a-c output from the high-voltage winding of a power transformer to a pulsating direct current. Pulsating means just that; the output of either a tube or a mineral diode in a rectifier circuit will flow in "spurts" or pulses in step with the frequency of the applied alternating current. For example, if 60-cps alternating current is injected into the input of a half-wave rectifier element, the pulses will occur at a rate of 60 per second. In a half-wave rectifier only one half of the a-c cycle is rectified and passed to the output of the rectifier at this rate. In a full-wave rectifier, *both* halves of the a-c input waveform appear at the output and will consequently occur at twice the input frequency, or 120 times per second. Both types of rectifier are used in radio applications. Refer back to Chapter 3, Fig. 3-1, for graphic illustration of both half- and full-wave rectification.

8-9 The tubes used in a vacuum-tube rectifier are either of the highly exhausted type or those characterized as mercury vapor. In physical construction they are identical as to base and envelope. Internally they contain no grid—merely one or two plates. In addition, the mercury-vapor tube also contains a small pool of mercury. Refer back to Chapter 3, paragraphs 3-12 and 3-14, for more detailed information on these tubes. Rectifier tubes of either type may contain either a *filament* or a *cathode*, the latter being heated indirectly by the equivalent of a filament but known as a *heater*. Diode rectifiers of the mineral type require neither a filament nor a heater. These may be used in half-wave, full-wave, or bridge circuits identical to those of the vacuum-tube types. Chapter 3 and Fig. 3-1 provide more data on such applications. Suffice it to say that the purpose of a rectifier (tube or crystal) is to change the raw ac issuing from the high-voltage secondary of a transformer to a pulsating direct current. You may be asked to identify "flashback" or "arcback" in a rectifier tube; stated simply, this occurs in mercury-vapor tubes as a result of *allowing the maximum inverse peak voltage to become excessively high, thereby causing the current to flow in the wrong direction.*

8-10 Next in line in the power supply is the filter system which directly follows the rectifier. Since this was discussed thoroughly in connection with examination element 2 in Chapter 3 (paragraphs 3-17 through 3-23 inclusively), there is no need to repeat this material here. However, it is necessary to add a bit of information with relation to filter capacitors to round out this subject. As was mentioned earlier, capacitors, like resistors, may be used alone, in series, in parallel, or in series parallel. If it represents the proper values of capacitance and voltage breakdown, one capacitor will suffice. Where greater voltage breakdown is required, capacitors may be connected in series, thus dividing the voltage between them. This will not be an equal division of voltage between them unless all of the capacitors so connected have the same value of capacitance. In a series connection the total overall capacitance of the string will be lowered, and in order to retain the desired value, capacitors of greater capacitance rating must be used. The various values required can be determined from the formulas shown in Fig. 8-2. Paralleling capacitors simply increases the overall capacitance of the bank, but the


C1
C2
C3
C4
TOTAL CAPACITANCE EQUALS: $\frac{1}{\frac{1}{C1}+\frac{1}{C2}+\frac{1}{C3}+\frac{1}{C4}}$
C1
C2
C3
C4
TOTAL CAPACITANCE EQUALS: C1 + C2 + C3 + C4

(A) Capacitors in series.

(B) Capacitors in parallel.

Fig. 8-2. Calculating capacitance.

voltage breakdown remains that of the lowest-rated capacitor in the group. Parallel capacitors are also shown in Fig. 8-2.

8-11 Only two elements remain to constitute a complete power-supply system. These are the filter chokes and the bleeder resistor or voltage divider. Resistors have already been covered in this chapter, and chokes, to a large extent, were explained in Chapter 3. However, a question reading somewhat as follows with respect to filter chokes is likely to appear in your examination:

Q. Why should a filter reactor (choke) not be operated beyond its rated capacity?

Ans. To do so would result in magnetic saturation of the core, which would in turn reduce the inductance of the choke, thereby making it less effective in the circuit.

8-12 The foregoing paragraphs, together with the power-supply information appearing in Chapter 3 in connection with examination element 2, will equip you to handle any questions which may be asked of you with relation to power-supply systems. There are, however, a number of additional electrical elements which may not appear as part of a power supply but are still purely electrical. These will be covered by the question-and-answer method which follows.

8-13 MISCELLANEOUS ELECTRICAL QUESTIONS

Q. How may the output voltage of a dynamotor be reduced?

Ans. By using a primary source of lower voltage than normal (fewer battery cells) to drive the motor portion of the dynamotor, or by insertion of a resistance (preferably variable) in series with the primary driving source. Either method will reduce the speed of the machine and thereby the voltage output. A resistor placed in series with the output terminals of the dynamotor will achieve the same results.

Q. Name a type of voltmeter that takes the least amount of power from a circuit to produce an accurate reading.

Ans. A vacuum-tube voltmeter, or any voltmeter of very high resistance.

Q. Many ammeters are provided with a shunt across their terminals. Why?

Ans. By shunting an ammeter, its range will be increased, allowing measurement of higher current values.

Q. What does the term "watt" signify? What is the formula for determining the wattage of a circuit?

Ans. Watt is the term by which the power in a circuit is designated. The wattage of a circuit is determined through the formula:

$$P = EI$$

where,

P represents power in watts,
E equals voltage,
I equals current.

Q. If two accurately calibrated ammeters are inserted in series in a circuit, how will their readings differ?

Ans. They will not; both readings should be identical.

Q. What two instruments can be used to measure peak a-c voltage?

Ans. An oscilloscope and a vacuum-tube voltmeter.

Q. To what does the term "power factor" apply?

Ans. Power factor represents the ratio between the actual power consumed and the theoretical value computed by multiplying volts by amperes.

Q. How does an autotransformer differ from a more conventional transformer?

Ans. Most transformers have two or more windings; an autotransformer has but one, usually fitted with one or more taps.

Q. What is the basic construction of a D'Arsonval ammeter?

Ans. A pivoted coil with an attached indicator pointer moves through an integral permanent magnetic field.

If resistors of unlike value are paralleled, the total current will be divided proportionately among them, but will, at the output end of the bank, total the same as the current value applied to the input. Questions with respect to resistors then could include the following:

Q. A current of 100 ma is applied to a bank of parallel resistors of different resistance values. What is the current after passing through the bank?

Ans. The same as that at the input: 100 ma.

Q. How is the input *voltage* affected by passing through such a bank?

Ans. It will be lowered, the value being determined by the total amount of resistance which the bank presents.

Q. How is the input voltage to a series string of resistors affected by passing through such a string?

Ans. The voltage will be lowered at the output in proportion to the added values of each individual resistor.

Q. In a circuit in which 125 volts are flowing at 250 ma, what is the circuit resistance?

Ans. 500 ohms.

Q. How did you arrive at this value?

Ans. By the use of Ohm's law, wherein $R = \frac{E}{I}$.

CHAPTER 9

Advanced Radio-Frequency Theory

9-1 In earlier chapters, considerable basic and elementary theory as related to radio-frequency applications has been covered. In the Extra-class examination additional questions relating to theory at a higher level will be interspersed among a number of questions of a practical nature; but since a majority of the latter are derived from theoretical considerations, they are also included as part of this chapter. Before entering into actual question-and-answer treatment in the following paragraphs, there are a number of definitions you will need to be familiar with in order to make intelligent answers to some of the formal questions. Most of these terms will be encountered frequently in discussions of power supplies, radio-frequency generation, and audio-frequency modulation. The simplest explanation of these various terms as is possible without destroying the clarity will be given. These definitions should be memorized, not only to provide you with material with which to answer the examination questions, but to have at the tip of your tongue in your daily amateur radio pursuits. Some terms will have additional meanings other than those used in radio/electrical applications. The term "resistance," for example, in its broad sense refers to opposition to some applied force; a heavy object, for instance, "resists" any attempt to lift or move it. Definitions, other than those specifically applicable to radio and electrical circuits, will be ignored.

RESISTANCE

9-2 Resistance is the extent to which an electrical conductor opposes a flow of electrical current. Resistance is measured in ohms.

CAPACITANCE

9-3 A capacitor is two or more electrically conductive plates separated by an insulating material known as the *dielectric*, which can receive and store an electrical charge. The amount of capacitor discharge depends on the demands of the circuit in which the capacitors are connected. Capacitors are rated in *farads*, but in electrical and radio applications which use relatively small values, the farad is broken down for convenience into *microfarads* (mfd), which represent millionths of a farad, and *picofarads* (pf), or millionths of a microfarad. The quantity of electricity which a capacitor can store is dependent on several factors: area of the plates, type and thickness of the dielectric material, separation between the plates, and the resultant capacity in microfarads or picofarads. The quantity of charge is designated in *coulombs* and is determined by the formula:

$$Q = CE$$

where,

Q equals the charge in coulombs,
E equals the voltage impressed across the capacitor,
C equals the capacitance in farads.

The capacitance of a capacitor can be calculated by:

$$C = 0.224 \frac{KA}{d} (n - 1)$$

where,

C equals the capacitance in picofarads,
K equals the dielectric constant of the insulating material between the plates,
A equals the area in square inches of one side of one plate,
d equals the separation in inches between plates,
n equals the number of plates.

DIELECTRIC CONSTANT

9-4 This term represents the ratio of the capacitance of a capacitor using no dielectric other than air between the conducting plates, to a dielectric of some solid material, such as mica, paper, glass, etc.

INDUCTANCE

9-5 Every conducting body (wire, metallic rod, tubing, etc.) has inductance. An *induced emf* (electromotive force), which is electrical power applied to a conductor, sets up a *back emf*, and these changing currents set up a magnetic field about the conductor. In a straight wire, or equivalent conductor, the inductance is small; if such a wire is wound into a coil with no core other than air, its inductance is increased. It is increased even more if the coil is wound on an iron core, as in transformers and filter reactors. The unit of inductance is the *henry*, and the inductance of an air-core coil can be calculated by the following formula:

$$L = \frac{a^2 n^2}{9a + 10b}$$

where,

L equals the inductance in microhenrys (μh),
a equals the radius of the coil in inches,
n equals the number of turns on the coil,
b equals the length of the coil.

Inductances connected in series and those placed in parallel behave the same as resistors so connected, and the same formulas apply as in Fig. 8-1 of Chapter 8.

REACTANCE

9-6 Reactance bears a close relationship to resistance in that it is an opposing force. The higher the frequency and the larger the inductance, the more opposition is offered to the flow of current through the inductance. This is termed *inductive reactance* and, like resistance, is measured in ohms. The formula for calculating the inductive reactance of a coil is:

$$X_L = 2\pi fL$$

where,

X_L equals the inductive reactance in ohms,
f equals the frequency in cycles per second,
L equals the inductance in henrys.

Capacitive reactance is also encountered in radio circuits. Here, frequency and *capacitance* rather than frequency and *inductance* are dealt with. The end result, however, is the same; opposition to the current flow is presented by capacitive reactance just as it is in inductive reactance. The formula for capacitive reactance is:

$$X_C = \frac{1}{2\pi fC}$$

where,

X_C equals the capacitive reactance in ohms,
f equals the frequency in cycles per second,
C equals the capacitance in farads.

IMPEDANCE

9-7 This definition is a simple one to remember, inasmuch as *impedance* is nothing more than a combination of both resistance and reactance. Two simple formulas will readily handle the determination of impedance. If resistance and reactance are in *series*, use the following formula to solve for total impedance:

$$Z = \sqrt{R^2 + X^2}$$

Where resistance and reactance are in *parallel*, the following applies:

$$Z = \frac{RX}{\sqrt{R^2 + X^2}}$$

where (in both formulas),

Z equals the impedance in ohms,
R equals the resistance in ohms,
X equals the reactance in ohms.

Q

9-8 In electronics, frequent reference is made to the *Q* of a component or circuit. This expression is a measure of "quality." The value of Q in a simple reactor can readily be found by the formula:

$$Q = \frac{X_L}{R_L}$$

where,

Q equals the quality factor or figure of merit,
X_L equals the inductive reactance in ohms,
R_L equals the resistance in ohms acting in series with the inductance.

The Q of a single capacitor is expressed as

$$Q = \frac{X_C}{R_C}$$

where,

X_C equals the capacitive reactance in ohms,

R_C equals the resistance in ohms acting in series with the capacitance.

OHM'S LAW

9-9 Ohm's law is the first basic formula that an amateur absorbs and is about as simple as they come. No doubt all of you know it forward and backward, but just to concentrate all of the commonly used radio/electrical formulas in one section, it is included here. Fig. 9-1 gives all the relationships between E, I, R, P, and Z.

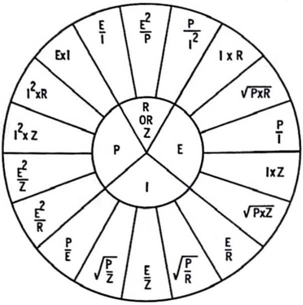


Fig. 9-1. Ohm's law.

FREQUENCY VERSUS WAVELENGTH

9-10 These two terms differ only in their manner of expression. A *wavelength* is measured in meters or centimeters, while frequency is measured in cycles, kilocycles, or megacycles. A wavelength of 500 meters, for example, is the same as a frequency of 600 kilocycles. The formulas for conversion of one to the other are:

$$f = \frac{3 \times 10^5}{\lambda}$$

where,
  f equals frequency in kilocycles,
  λ equals wavelength in meters.

When using megacycles and centimeters,

$$f = \frac{3 \times 10^4}{\lambda}$$

where,
  f equals frequency in megacycles,
  λ equals wavelength in centimeters.

From frequency to wavelength the following applies:

$$\lambda = \frac{3 \times 10^5}{f}$$

where,
  λ equals wavelength in meters,
  f equals frequency in kilocycles,

or,

$$\lambda = \frac{3 \times 10^4}{f}$$

where,
  λ equals wavelength in centimeters,
  f equals frequency in megacycles.

RESONANCE

9-11 The following formulas will be useful in calculating any series or parallel resonance problems which you may encounter.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{1}{4\pi^2 f^2 C}$$

$$C = \frac{1}{4\pi^2 f^2 L}$$

where,

f_r is the resonant frequency in cycles per second,
L is the inductance in henrys,
C is the capacitance in farads.

DECIBELS

9-12 The decibel is the standard unit to express transmission gain or loss and selective power levels. The circle chart in Fig. 9-2 gives all the equations for problems involving decibels.

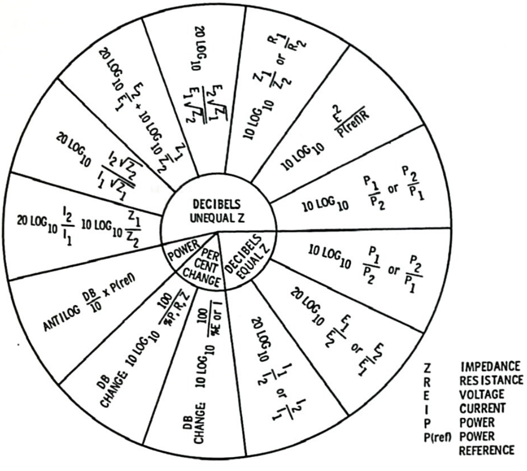
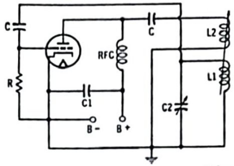
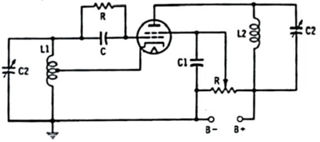


Fig. 9-2. Decibel formulas.

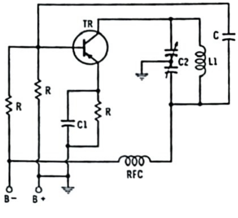
9-13 While the foregoing definitions and formulas do not by any means represent *all* of those used in radio and electrical calculations, they *do* fairly well cover the more commonly used mathematical expressions as applied to amateur radio design, construction, and operating techniques. If you are familiar with all of them, you should encounter little if any difficulty in solving the majority of problems which may be presented to you in the form of mathematical questions in your examination. The most practical method by which to learn these formulas thoroughly is to methodically take each one, set it up by using figures of your own for the various values, and work a number of problems. Having mastered one formula completely, proceed to the next, and so on down the list. Come back to these, choosing at random, from time to time during your study so that use of them remains fresh in your mind;



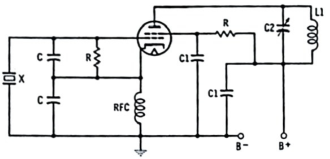
(A) Triode Armstrong oscillator.



(B) Electron-coupled tetrode oscillator.



(C) Colpitts transistor oscillator.



(D) Frequency-multiplying crystal oscillator.

KEY TO SYMBOLS

C - BLOCKING CAPACITOR.
C1 - BYPASS CAPACITOR.
C2 - TUNING CAPACITOR
R - RESISTOR.
L1-L2 - INDUCTANCES.
RFC - RADIO-FREQUENCY CHOKE.
TR - TRANSISTOR

Fig. 9-3. Miscellaneous r-f oscillators.

you will find them valuable adjuncts to the knowledge you have stored away with which to meet the examination questions which will face you.

9-14 In Chapter 8 the power-supply material of Chapter 3 was expanded to encompass the more advanced practice which the Advanced- Extra-class examinations call for. This approach will be continued in this chapter by elaborating on some of the r-f material presented in Chapters 4 and 5, as well as including additional data of a more advanced type.

Again the logical start for an r-f discussion should be built around the r-f generating system, the radio-frequency oscillator. In Fig. 4-1 of Chapter 4 a number of basic oscillator circuits were illustrated. While being representative of those in most popular use, other oscillating circuit arrangements are entirely practical, and one or more of these could well be included in element-4 examination questions. In Fig. 9-3 several additional oscillator circuits of both the vacuum-tube and the transistor types are shown. Familiarize yourself with these circuits as well as those of Fig. 4-1, and you will be well equipped with knowledge of oscillator circuit diagrams.

Along with possible drawings of oscillator circuits, you can expect a number of questions in this connection as well. The ones which follow are representative of some of those which you might receive:

1. What crystal cut is ordinarily used on frequencies of 5.0 mc and above, and why?

Ans. The BT-cut crystal is preferable by reason of its being a thicker cut than the AT type generally used for lower frequencies. The BT cut is therefore less likely to fracture (Fig. 4-2, Chapter 4).

2. Show a schematic diagram of a crystal oscillator that is capable of generating a harmonic frequency of the crystal without requiring a separate stage of frequency multiplication.

Ans. Use Fig. 9-3D.

3. What can be the result of the application of excess r-f voltage to a crystal oscillator stage?

Ans. The crystal is subject to fracture if the r-f voltage is excessive.

4. Should a crystal oscillator be permitted to operate without a load? If not, why not?

Ans. No, the r-f voltage becomes excessive, and the crystal may fracture.

5. Why is the tuned circuit of a crystal oscillator adjusted to a slightly higher frequency than that of the crystal?

Ans. To provide greater circuit stability.

6. What precautions should be taken to minimize the frequency drift of an oscillator?

Ans. Oscillator components should be located as far as possible from heat-generating equipment, such as vacuum tubes and resistors. They should also be metallically shielded from other components, and the circuit wiring should be of heavy wire not subject to vibration movement. The tank circuit should be of the high-C type.

7. What is the usual source of grid bias in an oscillator circuit?

Ans. This is generally obtained from a grid resistor and is termed "self-bias."

8. Is the stability of a crystal oscillator greater than that of a self-excited type? If so, why?

Ans. Yes; the crystal functions to hold the frequency of the circuit constant at that frequency for which the crystal has been ground.

9. What advantage does a self-excited oscillator have over a crystal-controlled type?

Ans. A self-excited oscillator may be tuned to any frequency within the range of its tuning components, whereas a crystal-controlled oscillator is limited to the frequency of the crystal being used.

9-15 Having covered the generation of radio-frequency current through the medium of oscillating circuits of both the fixed- (crystal) and the variable-frequency types, we can now pass to the next stage in a radio transmitter. While oscillators are perfectly capable of acting as a complete transmitter radiating energy into space, they are rarely used in this capacity because of their limited power-generating capacity and their tendency to also radiate various harmonic and spurious frequencies which are illegal. A transmitter of good design, even in the low-power category, almost invariably consists of an oscillator stage followed by a buffer or intermediate amplifier stage. Such an amplifier in a well-designed circuit may also render a good account of itself if it is chosen to represent the final amplifier of the transmitter. As a final amplifier, it may also serve as a frequency multiplier for the harmonic radiation of the oscillator frequency. This latter use is, however, a process calling for excellent design and intelligent adjustment and operation; the more accepted practice is to introduce a separate stage between the oscillator and the final amplifier for the purpose of frequency multiplication. Inasmuch as buffer and intermediate amplifiers as well as frequency multipliers have much in common, they are lumped in the following series of questions.

1. Assuming that an oscillator stage is followed by one which feeds the radiating system directly with no intermediate stages, what term is used to describe such following stage?

Ans. This is called the "final" or "power" amplifier; the terms are interchangeable.

2. What term is descriptive of a stage which is inserted between the oscillator and the final amplifier?

Ans. Dependent on the use to which such stage is to be put, it is known as an "intermediate" r-f amplifier or a "frequency multiplier."

3. Understanding that an intermediate r-f amplifier is provided as a means of increasing or amplifying the output of a preceding stage before passing it to the next, does it serve any other purpose?

Ans. Yes, it has a tendency to attenuate the amplification of any unwanted harmonics or spurious oscillations.

4. Does an intermediate amplifier tube require neutralization?

Ans. If it is of the triode type, it should be externally neutralized. A tetrode or pentode tube in such a stage rarely requires neutralization since the screen grid in these latter tubes effectively balances out the interelectrode capacitance within the tube.

5. How does a frequency multiplier differ from an intermediate amplifier?

Ans. Essentially, their circuitry is the same. Different voltage and current values are generally used, and the frequency multiplier most often operates at relatively low plate input for better stability; this lower input results in less amplification in a frequency-multiplying stage than in an intermediate amplifier.

6. Draw a schematic diagram of a frequency-multiplying stage.

Ans. Choose either (A), (B), or (C) of Fig. 5-1, Chapter 5.

7. Are frequency-multiplying stages customarily neutralized? If not, why not?

Ans. No, there is little tendency to self-oscillation as both the grid and the plate circuits are tuned to frequencies which are well separated.

8. May more than one stage of intermediate amplification be used in a radio transmitter?

Ans. Yes, ordinarily this is limited to two, either with or without a frequency-multiplying stage, or one of the intermediate amplifiers may be used as a frequency multiplier.

THE FINAL AMPLIFIER

9-16 The balance of this chapter is devoted to the last stage in a transmitter and the transfer of its r-f energy into the radiating system. The treatment here will be an expression of the material appearing in Chapters 5 and 6, using short explanatory text, a number of drawings, and questions and answers. Inasmuch as the various classes of amplifiers (A, B, AB, and C types) have been mentioned, they should be defined a bit further since practically all amplifiers used in amateur practice fall into one of these four general classes.

9-17 The class-A amplifier can be used as either a voltage or a power amplifier. The grid bias and a-c voltages applied to the grid of a tube connected for class-A operation are such that plate current flows through the tube at all times, with or without an applied signal. The power output of a class-A amplifier is much less than that available from a class-B amplifier, but the fidelity of the class A is much higher than that of the class B; therefore class A is most frequently used in the various stages of radiotelephone work where high fidelity is a desirable factor.

9-18 An amplifier designed for class-B operation is biased approximately to cutoff value (the point where the plate current is practically zero) and conducts for about half of each cycle when a signal is applied to the grid. Some manufacturers offer what are known as *zero-bias* tubes and, as their name implies, they require no form of bias.

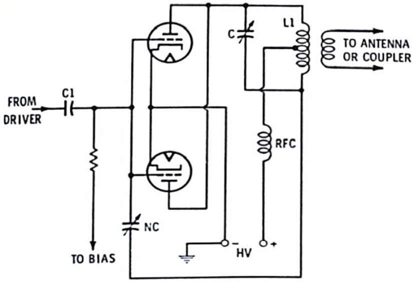
9-19 A combination of both the class-A and the class-B amplifiers, known as class AB, takes advantage of the desirable characteristics of each type, having the low-distortion capability of the class-A amplifier as well as the greater efficiency and consequently higher power output of the class B.

9-20 In class-C amplifier operation, the grid is biased beyond the cutoff point of the tube and the plate current is zero with no signal applied. When an a-c voltage is introduced at the grid, plate current flows for appreciably less than one half of each cycle. The class-C amplifier enjoys its greatest popularity as the final amplifier in r-f applications because its plate efficiency is high, averaging around 70%.

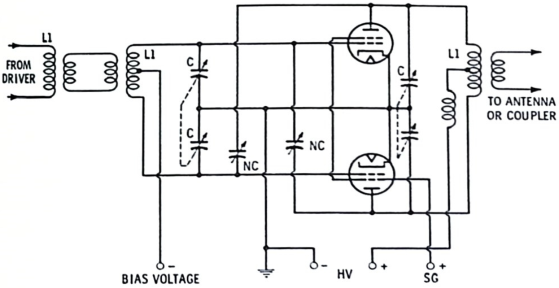
9-21 Grid bias is another term frequently encountered, and it is an important element in vacuum-tube operation, extending right on through the power amplifier. This subject was discussed in Chapter 5, but for answers to possible questions in examination elements 4(A) and 4(B), it should be amplified a bit more here. A simple definition of grid bias is to merely state that it is a *relatively low negative voltage applied to the grid of a tube*. Paragraph 5-13 of Chapter 5 suggests several sources from which such voltage may be obtained. This voltage serves to control the plate and grid currents of a tube, and a very small change in bias *voltage* will provide a far greater change in plate *current* than would be produced by adjustment of the plate voltage. Tube manuals, charts, and tables almost invariably specify the amount of rated grid *current* for which the tube was designed. The *voltage* requirements vary so widely depending on the use of the tube, that this value is seldom specified. In amateur radio construction manuals and articles having to do with devices using electron tubes, the negative grid voltage is generally stated; this will be set at a value which will permit the desired grid current. This latter should not exceed the manufacturers' rating; by so doing, the tube can be easily damaged.

Most manufactured transmitters have provision for determining the grid *current*, either by use of a separate grid milliammeter built into the panel face or through the use of a dual-scale meter which can be switched to read either grid or plate current. The grid-current reading is an accurate means of determining the proper amount of "drive" to the input of a following stage. Manufacturers of both complete transmitters and those in kit form generally carry a statement in their instruction manuals cautioning against exceeding the maximum rated current.

9-22 Final amplifiers are not necessarily confined to a single tube acting in that capacity. One arrangement which achieved a fair measure of popularity in earlier days and is still in rather common use is the connection of two tubes (sometimes



(A) Parallel triode circuit is identical to single-tube circuit with elements of second tube parallel to first.



(B) Push-pull tetrodes with grid circuit link-coupled to the preceding amplifier stage.

KEY TO SYMBOLS

C	TUNING CONDENSERS.	RFC	RADIO-FREQUENCY CHOKES.
C1	COUPLING CAPACITOR.	SG	SCREEN-GRID VOLTAGE.
NC	NEUTRALIZING CAPACITORS.	HV	FINAL-AMPLIFIER PLATE VOLTAGE.
L1	TUNING INDUCTANCES.		

Fig. 9-4 Parallel and push-pull r-f amplifiers.

even more) of like characteristics in parallel. This means that their elements are connected together and the pair of tubes connected into the circuit as though they were a single tube. This results in twice the power output of a single tube, and the grid drive from the preceding stage need be no more than that required for one tube. There are, of course, some disadvantages to a parallel arrangement. Suppression of harmonics and spurious radiations are more difficult to control, and neutralization must be very carefully accomplished. Parallel connection also requires rather close *matching* of the characteristics of the two tubes to deliver the best performance. If the balance is not close a weaker tube has a tendency to pull the stronger one down and the result is about the equivalent of two weak tubes. Parallel connection of tubes is indicated in Fig. 9-4A.

9-24 A better system for employing two tubes in a final amplifier is that known as the *push-pull* method. In this arrangement the two tubes cooperate with each other; in other words, one "pushes" and one "pulls" and this action alternates. Twice the grid drive required for a single tube is necessary from the preceding stage for push-pull operation. The electrical balance or matching of the two tubes is, however, less significant than for tubes used in parallel operation. Sometimes a combination of the parallel and push-pull arrangements is used. Here two pairs of tubes are connected in parallel; each *pair* is then considered as a single tube and the two *pairs* are arranged in a push-pull circuit. Push-pull circuits are found not only in r-f power amplifiers but in audio amplifiers and intermediate stages of a transmitter as well.

The *term* linear is sometimes applied to amplification. This does not necessarily require two tubes in push-pull; it can be used with a one-tube or single-ended amplifier. Linear amplification is generally used in audio applications, in a class-B arrangement to amplify a signal which has been modulated at a lower level. Such a system is not too widely used since the efficiency of this system is low, approaching that of grid modulation of the final amplifier. It is, however, a method that is economical from the standpoint of the cost of modulation components, and this is generally the governing factor in using a linear amplifier.

9-25 Based on the preceding paragraphs dealing with the final amplifier, suppose you test your knowledge by a series of questions.

1. Name the four most commonly used classes of r-f amplification.

Ans. (1) Class A; (2) Class B; (3) Class AB; and (4) Class C.

2. What are two major distinctions between class A and class B?

Ans. The power output of a class-A amplifier is considerably less than that of a class B, but it has excellent fidelity whereas the class B produces a distorted signal.

3. To what degree is the class-B amplifier biased?

Ans. To practically cutoff value.

4. Define the type of amplifier known as class AB.

Ans. A class-AB amplifier is one which combines the greater efficiency and power output of the class B with the low distortion characteristics of the class A.

5. What is the major characteristic of a class-C amplifier?

Ans. High efficiency, averaging about 70%.

6. What purpose does grid bias perform?

Ans. Grid bias serves to control the plate and grid currents of a tube to an extent which does not permit the plate current to become excessive when no excitation is applied to the grid. This function is often referred to as "protective bias."

7. How is the grid current of a vacuum tube measured?

Ans. By a milliammeter.

8. Draw a simple diagram of two triode tubes connected in parallel in an amplifier circuit.

Ans. Use the circuit of Fig. 9-4A.

9. What precautions should be taken in setting up an amplifier using parallel-connected tubes?

Ans. Both tubes should be electrically matched; neutralizing should be carefully performed.

10. To operate two tubes in a parallel amplifier circuit, what value of grid drive is required from a preceding stage?

Ans. The same value as that required for a single tube.

11. How does the power output of a parallel-connected amplifier compare with that of a single tube?

Ans. A parallel-tube amplifier has twice the power output of a single tube.

12. Show by simple schematic diagram, a "push-pull" type amplifier.

Ans. Use Fig. 9-4C for this answer.

13. What value of grid-driving power is required for push-pull operation?

Ans. Twice the grid-drive value required for a single tube.

14. To what extent is harmonic and spurious radiation a factor in a push-pull amplifier as compared to one using paralleled tubes?

Ans. Harmonic and spurious radiation is more easily suppressed in a push-pull stage than in a parallel-connected amplifier.

15. As in the parallel-connected amplifier tube arrangement, do the tubes in a push-pull amplifier require careful electrical matching?

Ans. Not to the extent called for in parallel operation although it is desirable to use tubes with as closely matched characteristics as possible.

THE RADIATED OUTPUT

9-26 Radiation systems and transmission lines were rather thoroughly discussed in Chapter 6, but some additional data will be of benefit in meeting the questions which you will very probably receive in your examination. For example, while types of transmission lines and lead-in wires and various antenna arrangements were discussed, the subject of antenna impedance was purposely left for this chapter. In a half-wave, center-fed Hertz antenna, which is a highly popular form of radiator, both r-f voltage and current appear on the antenna, and the center is the point of highest current. Such an antenna is referred to as being *current-fed.* The impedance at any point is equal to the voltage divider by the current and the lowest impedance exists at the point where the current is highest. In the half-wave, current-fed antenna, this means that the lowest impedance will occur at the center. This value is about 73 ohms. Obviously, to match this impedance to the transmission line, one of the readily available feedline types, such as *RG-11/U* or the physically smaller *RG-59/U* coaxial cable would be very close to a perfect match. While such a line offers an impedance match at the point of connection to the antenna, the transmitter output must also be matched to the input end of the transmission line. This is a function of either the pi-network output of the transmitter or a separate antenna coupler/impedance-matching device which has been previously discussed. If a Marconi-type antenna (which is used against an earth ground) is used, it can be considered as being one half of the center-fed Hertz, with the other half being represented by the earth as a conducting plane. The feed point would still be at the high-current point for lowest impedance, which in a quarter-wave vertical working as a Marconi would be at the base of the radiator. The base would represent the center of the radiating system when you remember that the earth replaces the other half of such a system. The antenna impedance can be considered as *radiation resistance*, which is a somewhat ambiguous term representing a resistance load substituted for the antenna. This substiuted load dissipates the same amount of power in *heat* as the antenna would dissipate in radiation. The power input to an antenna can be calculated by determining its radiation resistance at the feed-point and applying the formula:

$$P = I^2R$$

where,

I is the antenna current at the input,

R is the radiation resistance.

P then would represent the power input to the antenna in watts. The most convenient means by which to measure the actual current in the antenna at the feeder connection point is by means of a radio-frequency ammeter which permits a direct reading of the actual value.

1. Where, on a half-wave antenna, does the point of highest current appear?

Ans. At the center.

2. How is the impedance value arrived at?

Ans. By dividing the r-f voltage by the r-f current.

3. At what point on a half-wave antenna does the lowest impedance occur?

Ans. At the center.

4. What is the average value of impedance at the center of a half-wave antenna?

Ans. 73 ohms.

5. What type of transmission line is suitable to feed such an antenna?

Ans. Any type of line with an impedance closely matching

73 ohms; the coaxial types known as *RG-11/U* or *RG-59/U*, rated at 72 ohms, are excellent. The molded type known as *Twin-lead* in the 72-ohm size is also ideal.

6. How does a quarter-wave vertical Marconi antenna working against the earth differ from a half-wave Hertz, other than physically?

Ans. The Marconi is essentially the same with the vertical element acting as one half of the resonant length of a half wave and the earth appearing as the other half. The radiation resistance would however be about half that of the half-wave Hertz, or approximately 36 ohms.

7. How can the power input to an antenna be calculated?

Ans. By using the formula $P = I^2R$, where I equals the r-f current at the antenna input, R equals the radiation resistance, and P equals the power input to the antenna in watts.

8. How may the antenna current at its input be measured?

Ans. By a radio-frequency (thermocouple) ammeter.

CHAPTER 10

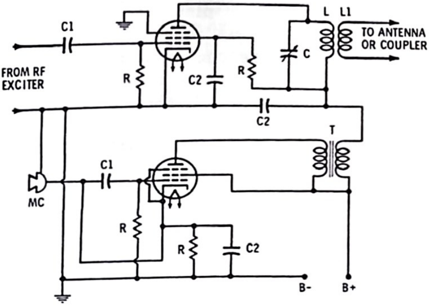
Advanced Audio-Frequency Discussion

10-1 Various modulation methods were described in Chapter 7, but examination element 4(B) will doubtless require considerably more specific data on various phases of modulation systems. With any subject as complex as current amateur radio transmission practice, it is impossible to cover in any one publication all of the circuits and equipment that can be used. Fortunately, inasmuch as the examination is of the multiple-choice answer type, very little matter will need to be written out in the way of an explanatory text to your answers. With the exception of several circuit diagrams, which you will probably be required to draw, and a number of formulas, simply marking the correct answer box for each question will constitute the major portion of your examination. Unless you understand the subject, you will not be able to correctly answer a sufficient portion of the questions to constitute a passing grade; that is why throughout this book, concise explanatory material has been presented to act as a guide in arriving at what you consider to be a correct answer. In the following paragraphs the subject of modulation will be expanded somewhat beyond that covered in Chapter 7.

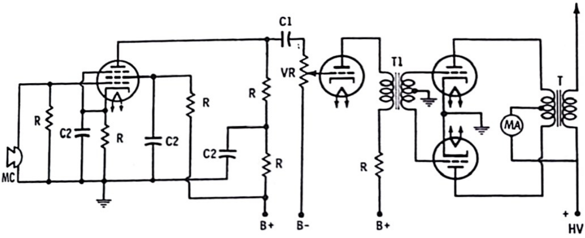
10-2 A major point to remember in dealing with modulation is that it concerns *audio* frequencies contrary to a purely radiotelegraph or c-w transmitter in which interruption of a pure r-f carrier by a telegraph key enables intelligent communication. When dealing with *audio* frequencies, tuned circuits composed of air-core inductors and variable capacitors are no longer used. The audio frequencies, whenever transformation of energy between stages is required, as for example, from the modulator to the radio-frequency amplifier, demand an iron-core inductor. Turn back now to Chapter 7 and examine Figs. 7-3A and B. Both of the transformers (T1 and T) are of the *iron*-core type, T1 transferring energy from the speech amplifier to the modulator tubes and T from the modulator stage to the final r-f amplifier. Note too that the plate voltage for the r-f stage passes through the *secondary* of the modulation transformer. The *modulator* tube, on the other hand, receives its plate voltage in series with the *primary* of the modulation transformer. In an arrangement such as this, if a d-c milliammeter is inserted in series with the r-f amplifier plate, it will be noted that with a modulation percentage of 100% or less, the plate current remains constant, either with or without modulation, and the indicator needle of the meter registers no deflection.

AMPLITUDE MODULATION

10-3 In the circuit shown in Fig. 7-3A, both a single-ended triode r-f amplifier and a single-ended triode modulator are shown. The modulator stage is operated as a class-A amplifier for best fidelity, but since it is of low efficiency, it has low audio-output power. A push-pull arrangement is capable of delivering more audio power and is to be preferred. Such a circuit, also using triode tubes, is shown in Fig. 7-3B. While simple triode tubes are shown to illustrate both the single-ended and push-pull r-f/a-f circuits, they are not limited to this type. For example, many amateurs prefer to use, rather than purely plate modulation, a combination wherein both the plate and the screen grid are modulated simultaneously. Obviously this calls for a tube with more elements than a triode; a tetrode or a pentode, both of which contain a screen grid, must therefore be used. Fig. 10-1A shows a pentode speech amplifier coupled to a pentode r-f stage through the modulation transformer (T). In Fig. 10-1B, a pentode preamplifier is resistance-coupled into a triode speech amplifier which in turn feeds its output into a push-pull triode modulator stage through an interstage coupling transformer. Resistance coupling, where it can be used, is the preferred method of interstage coupling because of its excellent frequency response and low component cost. Pentode tubes are almost always coupled to the following stage in this manner. Transformer coupling, as shown, between the speech amplifier and the modulator is generally used to couple to a push-pull modulator stage, to take advantage of the greater voltage gain of the transformer which the push-pull arrangement demands.



(A) Pentode modulator transformer-coupled to pentode r-f stage.



(B) Pentode preamplifier resistance-coupled to a triode speech amplifier which is transformer-coupled to modulators.

KEY TO SYMBOLS

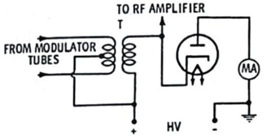
C--TUNING CAPACITOR
C1--BLOCKING CAPACITOR
C2--BYPASS CAPACITOR
R--RESISTORS
VR--VARIABLE RESISTORS
T1--INTERSTAGE TRANSFORMERS
T--MODULATION TRANSFORMER
MA--MILLIAMETER
MC--MICROPHONE (CRYSTAL OR DYNAMIC)
HV--FINAL HIGH-VOLTAGE SUPPLY

Fig. 10-1. Miscellaneous modulation systems.

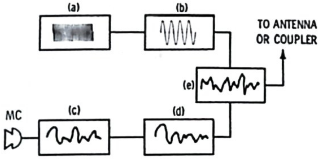
10-4 A modulation arrangement such as the one shown in Fig. 10-1B is perfectly capable of 100% modulation, which is the legal maximum. It is also entirely possible to overmodulate or undermodulate a transmitter using this system. The variable resistor (VR) is the audio-gain control of the system; it permits adjustment of the percentage of modulation. In order to make proper adjustment, some means of determining the percentage of modulation being realized must be employed. One method is to observe the plate-current meter of the r-f stage while adjusting VR. By increasing the output of the modulator, a point will be reached where the meter will show some slight movement. This is a good indication of 100% modulation, and the value of VR should be reduced slightly to eliminate all movement of the r-f meter pointer. This adjustment will produce approximately 95 to 98% modulation, which is adequate for amateur radiophone operation. If the r-f stage is equipped with a thermocouple r-f ammeter in the antenna circuit, its reading should increase approximately 20 to 25% during modulation. A steady tone from a buzzer, audio-frequency oscillator, or a similar audio note should be used to check this, rather than using voice. The latter will cause variations in the reading in accordance with the voice inflections. If an oscilloscope is available, the vertical plates can be coupled to the output of the final r-f amplifier and, with the internal sweep operating, the waveshape of the modulated output can be seen on the oscilloscope screen. Such patterns will closely resemble those of Fig. 7-1 in Chapter 7. For purposes of indicating only a condition of overmodulation, a *peak-modulation monitor* can be made up using a diode in series with a d-c milliammeter connected across the r-f plate-voltage supply at the modulation transformer. The meter should show no reading unless overmodulation occurs. The simple circuit of such a monitor is shown in Fig. 10-2A. Fig. 10-2B shows, by simple block diagram, the various waveshapes found in both the r-f and the audio sections of an amateur radiotelephone transmitter.

FREQUENCY MODULATION

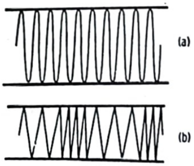
10-5 While frequency modulation is used to some extent in the amateur field, its popularity is not great, although it does present some desirable advantages. In a properly designed f-m receiver, the response to many forms of noise is attenuated, and the received signal is therefore relatively interference free from this source. Also, very little audio power is required for modulation; hence, simple circuits and low-cost components are possible. The f-m method, rather than varying the *amplitude* of the radiated energy, varies the radio *frequency* of the carrier in accordance with the impressed audio frequency. A graphic representation of this appears in Fig. 10-2C, where it will be seen that the r-f cycles in a frequency-modulated carrier vary in their spacing or frequency of occurrence. This is constantly changing in following the inflections of the hu-



(A) Peak-modulation indicator.



(B) Various waveshapes through radio- and audio-frequency stages.



(C) Constant carrier of amplitude modulation (a) and modulated f-m carrier (b).

KEY TO SYMBOLS

T--MODULATION TRANSFORMER
MA--D-C MILLIAMETER
HV--HIGH-VOLTAGE TERMINALS
IN (B)--THE FOLLOWING SYMBOLS APPLY:
(a)--R-F OSCILLATOR
(b)--INTERMEDIATE R-F AMPLIFIER
(c)--SPEECH AMPLIFIER
(d)--MODULATOR
(e)--R-F POWER AMPLIFIER
MC--MICROPHONE

Fig. 10-2. Modulation monitor and waveshapes.

man voice. The f-m system is capable of high fidelity and is used rather extensively by broadcast and commercial television stations, particularly those concerned with musical offerings which demand the highest possible fidelity. Amateur radio voice communication hardly calls for fidelity to this extreme, and, since relatively few amateurs are equipped with receivers of such design as to effectively accept this type of reception, f-m is not the more popular method of modulation for amateur communication.

10-7 Single sideband, although held in rather high favor by one school of amateur radiophone operation, also introduces complications just as in frequency modulation and reception. The average amateur communications receiver designed for effective a-m reception functions poorly in receiving single-sideband signals and requires considerable skill in operating techniques to produce an acceptably intelligible signal. It must be said, however, that single-sideband transmission promises some rather attractive future development. Currently it can be said to be going through a phase of experimental operation which offers almost unlimited opportunity for development on the part of those seriously interested in this mode. Sufficient operational progress has already taken place in this field to warrant publication of complete manuals dealing with nothing but single-sideband, or "ssb," transmission and reception. Until greater development, progress, and more popular acceptance are accorded ssb systems, it is probable that you will be concerned with little relating to this subject as a part of the Extra-class license examination. For those readers to whom the pursuit of further knowledge of ssb transmission is attractive at this time, it is strongly recommended that you procure one or more of the current books devoted to this subject; you will find this subject covered but briefly in most of the general-type amateur handbooks; some even ignore it completely in its present state of development. On the other hand, many national manufacturers are pushing ssb equipment, much of it being of the "transceiver" type that provides rather excellent sideband transmission and reception. Such activity on the part of these manufacturers should speed development of this communication method and increase its popular acceptance. The descriptive literature offered by these manufacturers will be found to be valuable adjuncts to whatever further study of ssb you choose to indulge in.

You will also run across some discussion of *dsb* or *double-sideband* transmission and reception; even more complications are presented here, but like ssb, it too seems to hold some promise of rather widespread acceptance in the not too distant future; meanwhile both modes offer a considerable challenge to the experimentally inclined amateur radio enthusiast. It is safe to predict, however, that regardless of what new developments may come forth in the next few years, a-m transmission in the amateur radiotelephone sense will remain for a long time to come.

10-8 With what is given in the preceding paragraphs, plus the treatment accorded to the subject of modulation in Chapter 7, you should by now have a pretty fair conception of speech amplification and modulation. Add to this the two-year minimum operation as a licensed General- or Advanced-class ham, plus the study of various other publications, and you should be fairly well equipped to handle any radiotelephone questions which may come your way. Suppose now that you try a few based on this chapter.

10-8 AUDIO-FREQUENCY QUESTIONS

1. In what major particular does radiotelephone transmission differ from the transmission of radiotelegraph signals?

Ans. In radiotelegraphy, the pure continuous radio-frequency carrier wave is interrupted by a telegraph key. Using the "dot-and-dash" symbols of the International radiotelegraph code, communication of intelligible meaning is accomplished. In radiotelephone transmission, the radio-frequency carrier wave remains constant in amplitude modulation, and audio-frequency tones such as the human voice are superimposed on the carrier, resulting in the reception of actual speech at the distant receiving point.

2. Draw a simple schematic of a single triode-tube r-f amplifier modulated by two triode tubes in a "push-pull" circuit.

Ans. Use Fig. 7-3B in Chapter 7 for this answer.

3. Show, by simple diagram, a single pentode-tube r-f amplifier plate-modulated by a single pentode tube.

Ans. Use Fig. 10-1A.

4. Rather than iron-core interstage audio coupling transformers in preamplifier and/or speech amplifier stages, what other interstage coupling is in popular use?

Ans. Resistance coupling, particularly with pentode tubes.

5. In a speech amplification system can both resistance coupling and interstage transformer coupling be used between stages?

Ans. Yes.

6. In an amplitude-modulated transmitter must such modulation always occur in the plate circuit of an r-f amplifier? If not, explain.

Ans. No, modulation of the control grid, of the plate and screen grid simultaneously, the suppressor grid, and cathode modulation can all be used.

7. Draw a schematic diagram of a complete plate-modulated a-m audio system using a resistance-coupled pentode preamplifier and a triode speech amplifier coupled to a push-pull triode modulator stage.

Ans. Refer to Fig. 10-1B for this.

8. Name two methods by which the percentage of modulation may be measured.

Ans. By observing the plate milliammeter of the final r-f amplifier stage and adjusting the modulation level so that no movement of the meter indicator needle can be observed during modulation. Another method uses an oscilloscope coupled to the r-f output stage. The waveshape of the emitted signal may then be observed and adjustment made until the oscilloscope pattern on the screen indicates 100% modulation.

9. How can overmodulation be detected?

Ans. By variation of the plate current in the r-f stage during modulation; by a pattern indicating overmodulation as observed on the screen of an oscilloscope; or by an increase in antenna r-f current in excess of 25%.

10. If a thermocouple r-f ammeter is inserted in the antenna circuit, what change in antenna current should be noted during modulation of approximately 100%?

Ans. The current reading of the meter should rise approximately 20 to 25% on modulation peaks. This is known as "upward" modulation.

11. Draw a diagram of a "peak-modulation monitor."

Ans. Refer to Fig. 10-2A.

12. Will such a monitor indicate percentage of modulation?

Ans. No; it will indicate only overmodulation.

13. How does frequency modulation (fm) differ from amplitude modulation (am)?

Ans. In amplitude modulation, the amplitude of the radiated modulated wave is varied by the power introduced in the sidebands by the modulating source. In frequency modulation, the amplitude remains constant but the frequency of the emitted wave is varied.

14. Show by block diagram the waveshapes and amplitude of both the radio frequency and the modulated audio frequency in a radiotelephone transmitter using (A) an r-f oscillator; (B) an intermediate r-f amplifier; (C) a microphone; (D) a speech amplifier; (E) a modulator stage, and (F) a final r-f power amplifier.

Ans. Refer to Fig. 10-2B.

15. Name one outstanding advantage of the single-sideband system of radiotelephone transmission.

Ans. Its ability to confine the radiated wave to a narrow bandwidth approximating about half the width of amplitude modulation.

CHAPTER 11

Advanced Class Study Material

The questions in this chapter are reproduced directly from material released by the Federal Communications Commission. They are classified by the FCC as study material and *do not* represent the actual questions which will appear on examination papers. They do, however treat in a similar manner the subjects covered and applicants may expect the examination material to reflect rather closely the treatment appearing in the study questions although with some paraphrasing.

In restoring the Advance-class license, issuance of which has been in suspension since 1952, a slower code speed requirement has been introduced and is now the same as required for the General-class license examination—13 words per minute. Holders of valid General-class licenses will therefore be given credit for the code portion of the Advanced-class examination, thus exempting them from repeating it.

The information in this book if carefully studied, should enable you to answer most of the questions in the Advanced-class amateur license exam. However, do *not* rely on study from one *text* book nor from any *one* source! Each publication which you peruse will add something to your knowledge. Simply by *reading* the material offered by others—whether you give it concentrated study or not—will cause many little bits of information to be absorbed subconsciously which may, and probably will, help you when you face the actual examination.

We emphasize that in the pursuit of knowledge leading to a chosen goal, whether it be in the professions, technical field or entirely unrelated to either, study of a large assortment of material variously authored, is a *requirement* on the part of all institutions of learning. This is no less true in preparing yourself for the higher grades of amateur radio licenses. There is a single, simple word which you should adopt right at the outset of your preparation—STUDY! Keep that as your foremost guiding principle and you cannot help but win!

1. Questions based on Part 97 of the Commission's Rules which govern the Amateur Radio Service.

Ans. While the foregoing is hardly a "question" it is indicative that familiarity with Part 97 of the rules is vital in that a number of questions relating to these will appear in the examination. Applicants should therefore be prepared to answer any questions relevant to this portion of the rules. The complete text is obtainable from the Supt. of Documents, Govt. Printing Office, Washington, D.C. 20402, and from a number of commercial publications. There is no need to memorize these rules nor to quote them word for word; just make sure that your answers to any questions bearing on them reflect the proper and complete *intent* of such rules.

2. What is a good indication that a high standing wave ratio (swr) is present on a transmission line? Where is the best point on a long transmission line to measure the swr?

Ans. An swr bridge instrument showing both forward and reflected power is the most commonly accepted device to indicate swr. Suspicion of a high ratio prior to actual measurement would be inability to load the output of a transmitter properly to its radiating element. Ordinarily, the lowest ratio will appear closest to the transmitter; this is particularly true of long lines or those with greatest integral losses. The most accurate reading will therefore be obtained at the point of actual connection of the transmission line to the load.

3. What methods are most commonly used to generate single sideband signals? Draw a block diagram of the filter method showing all essential stages. How can a low frequency ssb signal be converted to the desired transmitting frequency?

Ans. One method for ssb signal generation is known as the filter system in which the audio output and that of the r-f oscillator feed into a balanced modulator which serves to suppress the carrier. A bandpass filter then receives the two sidebands, passing one and rejecting the other. Converting a low frequency ssb signal to the desired transmitting frequency can be accomplished by use of an oscillator and mixer. The output may then be tuned to the transmitting frequency desired. A block diagram of the filter method of ssb generation appears in Fig. 11-1.

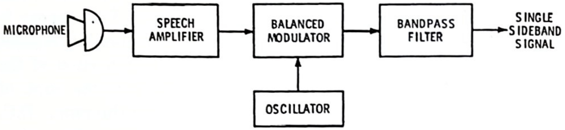


Fig. 11-1. Block diagram of filter method of ssb generation.

4. What happens to the voltage, current and impedance along a transmission line with an swr of 1?

Ans. An swr of 1 represents unity and is attainable only if the load is perfectly matched to the line. This condition is possible only if the line has zero loss which, while theoretically possible, is seldom true in practical application. With reasonably low line losses, the value of both current and voltage along the line will not vary and will be in phase.

5. What are harmonics? How can the generation of excessive harmonics be avoided?

Ans. Harmonics are multiples of the fundamental frequency. The second harmonic is twice the frequency of the fundamental, the third is three times the frequency, etc. Undesired harmonics can be reduced or eliminated through proper adjustment of the transmitter output stage, reduction of grid drive from stages preceding the final amplifier, use of antenna matching device (coupler), and reduction of output coupling to the load.

6. What factors affect the state of ionization of the atmosphere?

Ans. The season of the year and time of day or night are the most common factors. While ionization is a variable in these respects, a sun-spot cycle occurring with regularity every 11 years has a prominent part in affecting ionization conditions.

7. What types of emission can be received with selectable sideband receivers?

Ans. Amplitude modulated signals, either radiotelephone or telegraph may be received on this type of receiver, either sideband radiated by transmitters of this type and continous wave (keyed constant carrier) radio telegraph transmissions.

8. The ratio of the peak envelope power to the average power in an ssb signal is primarily dependent on what?

Ans. The modulated waveform determines this. With a single steady or dual tone modulation the ratio, peak envelope, and average power will be the same; with voice modulation the voice characteristics will be the determining factor.

9. How can receiver sensitivity and selectivity be improved?

Ans. Providing additional tuned r-f amplifier stages, decreasing r-f bandwidth, provision of a crystal or mechanical filter, and/or use of a notch filter will all contribute to improved sensitivity and selectivity.

10. How close to the edges of a certain amateur band can you safely operate a vfo c-w transmitter if you are using a frequency meter having maximum possible error of 0.01%?

Ans. Multiplying the frequency of the selected band edge by the percentage of error in the frequency meter and adding the keying bandwidth determined by the shape of the keyed waveform will produce the frequency figure which may be used.

11. A transmission line that feeds an antenna has a power loss of 10 db. If 10 watts are delivered to the transmission line input, how much power is delivered to the antenna? List possible causes of power loss. How can the swr of the line be made as low as possible?

Ans. One watt would be delivered to the antenna. Radiation from the transmission line, dielectric loss, and resistance in the conducting medium of the line are all common causes of power loss. The swr of a line can be minimized by closely matching the line and antenna impedance.

12. How do parasitic oscillations affect circuits? What can be done to prevent or eliminate parasitics?

Ans. Parasitics can cause breakdown of components and wiring. They also represent a power loss in the final output circuit. Their prevention and/or elimination can be accomplished by neutralizing, adequate circuit shielding, and often by insertion of a parasitic choke in the plate lead of the final amplifier tube.

13. What is backwave radiation? How can it be eliminated?

Ans. Backwave results from radiation when the key is open. It generally appears when a final stage is keyed in such a manner that the final amplifier output is not reduced to zero in the open-key position, thereby allowing oscillation from preceding stages to leak through to the output. Backwave can also result with keying in stages preceding the final amplifier if inadequate stability has been provided in the lower powered stages. Lack of neutralization in any stage normally requiring it can cause generation of parasitics. These oscillations will readily pass through to the final stage and be radiated on undesired, and often illegal, frequencies even with the key open; the remedy is obvious.

14. Define maximum usable frequency.

Ans. This represents the highest frequency (abbreviated MUF) which can be used for reliable communication between selected points without encountering ionospheric reflection or "skip effect" causing the radiated signal to appear at a point beyond that desired.

15. A resistor, capacitor, and inductor each have 100 ohms of resistance or reactance. What is the equivalent series impedance of these three elements?

Ans. 100 ohms by reason of cancellation of capacitive and inductive reactance, a characteristic of these two elements in series.

16. What do oscilloscope patterns showing 50% and 100% modulated signals without distortion, look like?

Ans. See Figs. 7-1A and B, specimen modulation patterns.

17. What are some common types of oscillators employed in amateur equipment? How can each be identified in circuit diagrams? What part does feedback play in these oscillators? What points in the circuit should be coupled to provide good feedback?

Ans. Most popular among the vacuum-tube oscillator circuits used in amateur equipment are the Pierce, Hartley, and Colpitts using triode or tetrode tubes. The Pierce is readily identified through lack of any variable tuning components; the Colpitts may be readily distinguished by its dual tuning capacitor or similar fixed capacitors connected across the inductance and cathode. The Hartley may be recognized by the cathode tap on the inductance itself. Feedback requires that a small amount of power from the plate (output) circuit be coupled back to the grid (input) circuit. To introduce and maintain oscillation, the input circuit must be in phase with the output circuit or must be regenerative. The plate and grid circuits of an oscillator obviously should be coupled.

18. Why is neutralization important in amplifiers? What points in an amplifier circuit should be coupled to provide good neutralization?

Ans. Neutralization is necessary when the internal grid-plate capacitance of a tube is not compensated for within the tube envelope itself. Without such neutralization, generation of parasitic oscillations at undesired frequencies will occur. An adjustable coupling arrangement to feed a small amount of power from the grid to the plate circuit will serve to effectively cancel out or neutralize the internal grid-plate capacitance.

19. When is an amplifier operating class A? Class B? Class C?

Ans. In a class-A amplifier the output voltage waveform is the same as that of the input voltage (I_p flows 360°). A class-B amplifier is known as a "linear" amplifier, one in which output power is proportional to the square of the input voltage (I_p flows 180°). In a class-C amplifier, the output varies as the square of the input voltage (I_p flows less than 180°).

20. What happens to even-order products in r-f linear amplifiers?

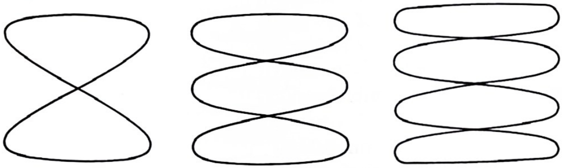
Ans. The output tank circuit accepts and disseminates them in the same manner in which harmonic suppression takes place.

21. What is a third party agreement? What countries have such agreements with the United States?

Ans. Such agreement is executed between two countries by mutual consent and permits the exchange of communication between amateur stations in the interests of persons other than the station licensees. Under varying restrictions, such third party message traffic may be exchanged by United States amateurs with these countries: Argentina; Bolivia; Brazil; Canada; Chile; Colombia; Costa Rica; Cuba; Dominican Republic; Ecuador; El Salvador; Haiti; Honduras; Israel; Liberia; Mexico; Nicaragua; Peru; Panama; Paraguay; Uruguay; Venezuela.

22. What are Lissajous figures in oscilloscope operation? What scope patterns would be produced if the signal applied to the horizontal input has a frequency equal to two, three, or four times the frequency of the signal applied to the vertical input?

Ans. Lissajous figures are the resultant stationary patterns appearing on an oscilloscope when two a-c voltages are applied to the vertical and horizontal deflection plates. Should a signal be applied to the horizontal input at a frequency of twice that applied to the vertical input, a figure-8 pattern would appear on the scope. (Fig. 11-2A). At triple the frequency the pattern shown in Fig. 11-2B results; at four times the frequency, the pattern in Fig. 11-2C appears.



(A) Two times frequency. (B) Three times frequency. (C) Four times frequency.

Fig. 11-2. Lissajous figure scope patterns.

23. How are bypass capacitors used? How should their impedance compare to the elements they shunt ?

Ans. Bypass capacitors provide a path for r-f energy while at the same time blocking the passage of unwanted energy associated with the circuit. They should be of low impedance with respect to the circuit element with which they are identified. The ratio of X_c to R should be $\frac{1}{10}$.

24. How can tvi caused by cross modulation be remedied?

Ans. A high-pass filter installed in the televevision receiver is generally effective. Sometimes a simple trap, tuned to the frequency of the unwanted signal will prove an adequate remedy.

25. How can ssb signals be amplified with little or no distortion?

Ans. A class A, B, or AB linear amplifier properly adjusted will minimize or eliminate such distortion while providing amplification.

26. A superheterodyne receiver having an intermediate frequency of 455 kc is to be adjusted to receive a signal on 3900 kc. What frequencies can the high frequency oscillator be set to, to give a beat signal at the intermediate frequency?

Ans. Either 455 kc above or below 3900 kc.

27. What circuit factors affect the peak envelope power of a transmitter?

Ans. In a ssb transmitter, peak envelope power is the maximum amount obtainable without distortion. Choice of grid bias, neutralization, and the l/c ratio in tank circuits all contribute to peak envelope power. In an a-m transmitter, peak envelope power is affected by grid bias, amount of loading in the modulated r-f stage, and the degree of excitation.

28. How does a full-wave bridge rectifier operate? What is the schematic diagram of this rectifier circuit?

Ans. A full-wave bridge rectifier uses four rectifying elements, two in series on each half of the supply cycle; one pair is connected to the load, the other in the return lead. Current flow is through one pair during one half of the cycle, through the other pair during the other half. A schematic appears in Fig. 11-3.

29. When can a low-pass filter be installed in a coaxial cable without causing a large power loss?

Ans. When the filter impedance matches the characteristic

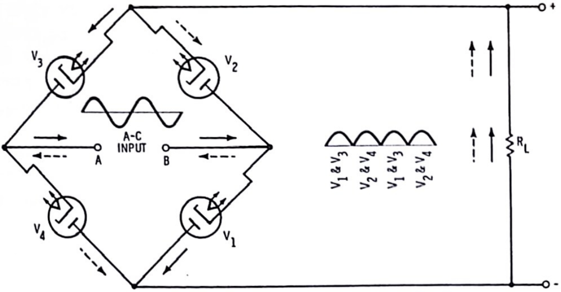


Fig. 11-3. Full-wave bridge rectifier.

impedance of the transmission line and the line itself is matched to the load.

30. How can the resonant frequency of an antenna be increased? Decreased?

Ans. Frequency may be increased by shortening the antenna or inserting a capacitance in series with it. It may be increased by lengthening or using a loading inductance in series with it.

31. A 70-ohm half-wave antenna operating on a frequency of 7300 kc is to be matched to a 50-ohm transmission line. Calculate the characteristic impedance of a quarter-wave matching section and the physical length of the antenna at the frequency given. What is the swr between the antenna and transmission line without a matching section?

Ans. The physical length of the antenna can be calculated by the generally accepted formula L=468/f where, L is the length and f the frequency in megacycles. Applied to the frequency in question (7300 kc) this would result in a length slightly greater than 64 feet; 64 feet would be acceptable for practical use. As the impedance of the antenna specified is 70 ohms and it is to be matched to a transmission line of 50-ohms impedance, a mismatch of 20 ohms would result. Multiplying the two impedances (line and antenna) produces the figure 3500, the square root of which is the impedance which the matching section over 59 ohms. Without the matching section, the swr between the line and antenna would be the ratio between these two, or 1.4/1; with the proper matching section, the swr would theoretically be unity or 1/1.

32. Power dissipation in what part of a transistor warrants careful observance of power ratings?

Ans. The junction of collector and base should be checked to avoid excessive heating.

33. Define the shape factor of a crystal lattice bandpass filter.

Ans. The shape value represents the selectivity of the filter. It is determined by the ratio of the bandwidth of the filter under high attenuation to the minimal filter passband.

34. Compare the pentode, tetrode, and triode for use in an r-f amplifier stage. Give advantages and disadvantages of each.

Ans. Pentodes and tetrodes, due to the inclusion of additional grid elements within their envelopes, present very low plate to control grid capacitance. They may be used in many cases without neutralization although sometime it is required in equipment of appreciable power. Amon their disadvantages is the requirement for a screen-grid power source and the necessity to modulate the screen as well as the plate for linear operation. Triodes, because of their high plate to control grid capacitance, usually require neutralization and a high value of grid drive. They have the advantage of requiring no power supply source other than that for filament (heater) and plate.

35. What is meant by describing a radio wave as horizontally or vertically polarized? Which type is most suitable for sky and ground wave propagation?

Ans. Magnetic and electrical lines of force at right angles to each other constitute a radio wave. If the electrical lines are perpendicular (magnetic lines horizontal) the wave is said to be vertically polarized. Conversely, a horizontally polarized wave results when the positions of these lines are reversed (electrical lines horizontal, magnetic lines vertical). Either vertical or horizontal polarization is suitable for sky wave propagation; however, horizontal polarization has a slight advantage over vertical polarization for ground wave propagation.

36. Which amateur band is the most suitable for daytime communication over a distance of about 200 miles?

Ans. While the 1.8 mc band will occasionally perform satisfactorily over this distance and the 3.5 mc band frequently, the 7.0 mc band has proven the most consistently reliable for such communication.

37. Should a voltmeter have high or low internal resistance?

Ans. High, because it is connected directly across the circuit to be measured. If it has a low resistance it will draw a heavy current itself and produce a less accurate reading.

38. A transformer with 155 volts applied across the primary terminals has a primary to secondary turns ratio of 10 to 1. If a 5-ohm load is connected to the transformer secondary, the reflected primary impedance is what? How much voltage appears across ½ of the turns of the primary?

Ans. The impedance ratio in a transformer being proportional to the square of the ratio of turns in the windings would reflect an impedance of 500 ohms in the example. One half of the primary input voltage would appear across ½ of the primary turns.

39. What function does a variable-mu tube perform in an r-f amplifier stage of a receiver?

Ans. A variable-mu tube by reason of control of its amplification factor through varying grid bias permits acceptance of a wide range of signal levels with minimum cross modulation and distortion.

40. Compare transistors and tubes. What are the advantages and disadvantages of each?

Ans. Compared to transistors, vacuum tubes have the advantages of (1) greater power handling capability; (2) low internal feedback; and (3) effective heat-dissipating ability. Their chief disadvantages are: (1) mechanical fragility; (2) relatively large physical size; and (3) greater power supply demands. The transistor offers (1) small physical size; (2) no warm-up period; (3) negligible power requirements; and (4) mechanical stability. Its chief disadvantages are: (1) limited power handling capability; (2) inability to withstand overloading; (3) heat dissipation requirements; and (4) critical neutralization in some applications.

41. How do noise limiters operate?

Ans. By limiting the level of noise impulses to that set for the desired signal level thus preventing impulse noise surges from exceeding that level.

42. How do inductors combine in series and in parallel? Capacitors in series and parallel?

Ans. Assuming no inductive coupling between inductors, the total inductance of two or more in series is equal to the sum of the inductance of each. In parallel with no coupling between inductors the total inductance (L) may be calculated by the formula:

$$L = \frac{1}{L_1 + L_2 + L_3 + L_4 \text{ etc.}}$$

Where only two inductances are connected in parallel the formula becomes:

$$L = \frac{L_1 L_2}{L_1 + L_2}$$

43. Define frequency deviation in f-m transmission.

Ans. The maximum frequency shift from the center or resting frequency occurring under full modulation.

44. How does the peak envelope power input of an amplifier used for c-w compare to the pep of a ssb amplifier when using the maximum legal d-c power?

Ans. Peak envelope power of a c-w amplifier is determined by the product of the d-c plate voltage and the d-c plate current. As ssb pep cannot be so determined as it varies with voice waveform, an arbitrary ratio of 2 to 1 is generally accepted as average. Therefore the pep of a ssb amplifier would be twice that of a c-w amplifier.

45. What are the advantages and disadvantages of using the same antenna for receiving and transmitting?

Ans. In using the same antenna, directional characteristics are favored in that reception of a strong signal would indicate that a similarly strong signal would be transmitted in that direction assuming equal power at both ends. In addition, the electrical size of a given antenna cut to respond to a definite frequency or small band of frequencies, will perform equally well for both transmission and reception. Mechanically a single antenna presents only half of the space requirement and reduces physical construction proportionately. Its main disadvantage is in requiring some means of switching between transmit and receive, either by mechanical, electrical, or electronic means.

46. What is the vacuum tube counterpart of (1) a grounded base circuit; (2) grounded emitter circuit; (3) grounded collector circuit?

Ans. Transistor elements may be likened to those of a vacuum tube as follows: base, grid; emitter, cathode; collector, plate. Therefore, a grounded base circuit would be the equivalent of a grounded grid, a grounded emitter would represent a grounded cathode and a grounded collector would simulate a grounded plate (cathode follower).

47. How does the sun spot cycle affect wave propagation? What are the best frequencies to use for day and night, short and long distance communications during the cycle?

Ans. The sun spot cycle is a phenomena of varying intensity occurring every eleven years although sun spots activity varies as well between day and night affecting the E, F_1, and F_2 layers. Such activity produces layers of ionization in the upper atmosphere which act as reflectors to bend radio propagation back to earth at angles dependent on the frequency of the radio emissions. Generally speaking, the 3.5 and 7 mc bands will provide most reliable short distance communication during the daylight hours. For greater distances the 14, 21, and 28 mc bands are most effective. At night, the 1.8 and 3.5 mc bands provide best short distance coverage and the 14 and 7 mc bands for the longer hauls. Sunspot activity has little effect on the higher frequency bands therefore no radical change in their communication capabilities is experienced from this factor.

48. How does automatic gain control operate? When can it be used for ssb operation? c-w operation?

Ans. By impressing direct current obtained through rectification on the amplified incoming signal a reduction in receiver gain results on a strong signal whereas little or no effect is produced on a weak signal. In both ssb and c-w reception, agc circuit constants should be such as to produce fast action with little or no delay time.

49. How should a linear amplifier be adjusted for linear operation?

Ans. If an oscilloscope is available the plate loading, grid bias, and r-f excitation should be so adjusted that the modulation peaks do not indicate a flat top characteristic at maximum r-f output. Lacking an oscilloscope a single tone can be used to modulate the amplifier and the r-f output brought to maximum by adjustment of plate load, grid bias and excitation. The excitation can then be gradually reduced until the output shows a pronounced drop. During normal operation the excitation should not exceed the point at which this occurs.

50. How is the power output of a 100% modulated a-m signal related to the carrier power?

Ans. With modulation, the output will be higher than with the carrier only. Voice modulation will produce from 10% to 30% increase but a single steady tone will increase the power output 50%.

51. Why does a type 6146 tube have three prongs connected to the cathode?

Ans. To reduce the inductance between the cathode and ground point which would otherwise produce undesirable feedback effects, particularly in the vhf bands.

CHAPTER 12

Extra Class Study Material

The scope of the questions and answers has been considerably expanded from that of the Advanced-class study material in this chapter. All of the study questions released officially by the Federal Communications Commission to cover the additional requirements now to be met in the Extra-class license examination are included here.

As with the Advanced class, we urge readers to study not only all of the material on the following pages but to extend their studies into other publications devoted to the subject. While answers to the questions will be found to be substantially the same in all reference material, the paraphrasing of the various authors will be most helpful in clarifying points for you that may appear somewhat vague in one publication. The more thorough your knowledge the better equipped you will be to obtain a passing grade in the examination on your first try.

Don't be inclined to gloss over any questions which you think you can readily answer without further study. While in some cases this may be true, you will be wise to review such subjects by reading whatever material is available to you to not only check yourself on what you may think is the correct answer but to refresh your memory on salient points which you may have overlooked or forgotten. The fact that you must answer correctly only three fourths of the questions you may receive should not lead you to conclude that the few with which you may not be completely familiar you can afford to miss. You do not *know* that these particular questions will be included or excluded from those which you will be asked. Knowing the correct answers to *all* of the following questions, plus what basic knowledge you can acquire from the preceding chapters, is your best assurance of making the grade.

As a further caution, remember that your code speed of 20 words per minute will not be judged on your *receiving* ability alone; a surprising number of applicants fail to pass the code test by reason of poor *sending!* If your fist is poor or mediocre, concentrate your code practice on your sending if you're satisfied that your receiving ability is adequate. Tape record your transmission if you can, using a code practice oscillator and then listen to yourself on the playback. You may find your own sending difficult for even *you* to read. You can then discover why and how to correct your spacing, character formation, or whatever is indicated before you appear for your formal examination.

1. What are sideband frequencies? During 100% sinusoidal amplitude modulation, what percentage of the average power is in the sidebands?

Ans. Frequencies which appear both above and below the carrier frequency are referred to as sideband frequencies; they serve to carry the modulated signal. With 100% sinusoidal amplitude modulation. the sidebands carry one third of the average power of 33⅓%.

2. What do the modulation envelopes of amplitude modulated waves with 50%, 100%, and greater than 100% modulation look like?

Ans. See Fig. 7-1, specimen modulation patterns.

3. How may a limiter be employed in an f-m receiver?

Ans. To prevent variations in amplitude of an incoming signal before the latter is detected.

4. What precaution (s) should be taken when measuring the rectified grid voltage in an oscillator with a d-c voltmeter?

Ans. A vacuum tube voltmeter is preferable for this purpose due to its high resistance and r-f choking effect. Lacking such an instrument the type of voltmeter available should have a very high resistance and an r-f choke should be fitted to its probe.

5. What is meant by frequency shift keying (fsk) and how is it accomplished?

Ans. Power in the radiated wave is held constant but the keying technique serves to shift between two frequencies slightly separated; these are commonly referred to as the "mark" and "space" frequencies. Any keying method which will serve to accomplish such frequency shift at a rate commensurate with that of the keying speed desired may be used.

6. Why is there a practical limit to the number of stages that can be cascaded to amplify a signal?

Ans. By reason of increased instability in succeeding stages with consequent danger of self oscillation through coupling between input and output circuits. As both natural static electricity and manmade noise are amplified to the same extent as a signal, nothing is to be gained by excessive amplification unless the signal-to-noise ratio can be improved too.

7. What are A5 and F5 emissions? On what amateur frequencies can these emissions be transmitted?

Ans. Transmission of A5 (amplitude modulated) and F5 (frequency modulated) television signals may be on any amateur bands above 420 mc.

8. How does amateur tvi usually affect television reception?

Ans. The r-f carrier from an amateur station can cause a pattern referred to as cross-hatching on the television screen; the intensity of this interference varies dependent on the strength of the carrier being received. If the carrier is being modulated, this modulation will appear as horizontal bars on the screen; these will be alternately dark and light and will appear in addition to the crosshatching pattern. Where modulation but no carrier exists as in an amateur ssb transmitter, both horizontal bars and crosshatching will appear but only with the modulated signal. Such patterns will vary in intensity with relation to speech modulation. Interference of this type generally occurs only on channels which may be harmonically related to the transmissions of the amateur radio station. The modulated signal may also be heard in the television sound, particularly in the higher frequency spectrum.

9. In what section of a properly operating ssb transmitting system is distortion most likely to originate?

Ans. The final amplifier stage of the transmitter is the most likely source of distortion. A properly adjusted ssb transmitter should be operating with no distortion.

10. What is the meaning of the time constant in a resistance-capacitance circuit?

Ans. When a charged capacitor is discharged through a resistor the number of seconds required for the voltage to decrease to 37% of its original value, is known as the time constant. Conversely it is the time in seconds required to bring the voltage of a capacitor being charged through a resistor to 63% of its final value. Stated as a formula:

$$T = R \times C$$

Where,

T is the time in seconds,
R is the resistance in megohms,
C is the capacitance in microfarads.

11. How does a squelch circuit operate? Draw a commonly used circuit.

Ans. When no signal is being received, the squelch circuit silences the audio output of the receiver. If adjustable, the squelch can be set so the receiver remains silent except when actuated by signals of a predetermined level. The actual squelching is provided by increasing the bias on the audio amplifier stage and restoring normal bias through a control tube when a signal of the predeter-

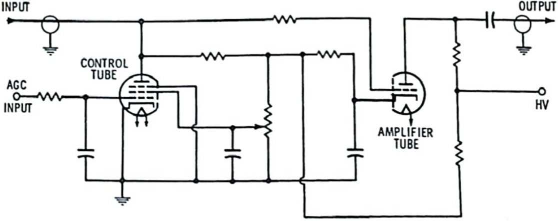


Fig. 12-1. Squelch circuit.

mined level appears. A commonly used squelch circuit appears below.

12 An oscilloscope is used to study the relationship between the input and output of an amplifier produced by a voice signal. How would the scope pattern display a linear relationship?

Ans. With a phase relationship of 0 or 180 degrees the voice pattern will be a straight line obliquely displayed. With phase relationships other than 0 or 180 degrees, an elliptical pattern will be produced in a series of ellipses, concentric and varying in size with voice modulation.

13. Draw a block diagram of an rtty system showing the function of each stage. What is the proper way of identifying an rtty transmission?

Ans. Identification of a radioteletype transmission should be made by making the call of the station called and the call letters of the calling station, using the teletype mode. This should be followed by the call letters of the calling station sent in the International radio telegraph code. The block diagram of an rtty system is shown in Fig. 12-2.

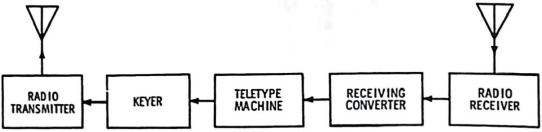
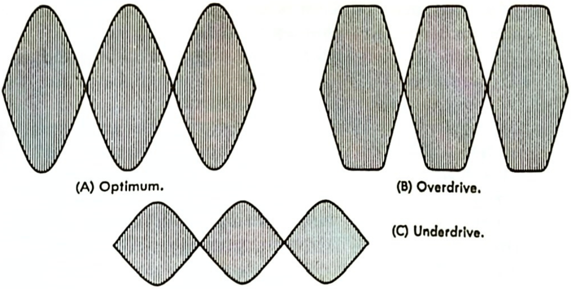


Fig. 12-2. Block diagram of a radioteletype system.

14. How can the two-tone test output of a linear amplifier be used to tell if a transmitter is working properly? Show scope patterns for optimum, underdrive, and overdrive conditions.

Ans. Using an oscilloscope to display the r-f output pattern is the most satisfactory method. By this means observation of the modulation pattern while adjusting the audio level will indicate the point at which flattening of the envelope peaks becomes evident (Fig. 12-3B). The point toward which to work is, of course, optimum which is indicated in Fig. 12-3A.

15. Define the alpha cut-off frequency of a transistor. How is this paramenter of use in circuit design?



(A) Optimum.

(B) Overdrive.

(C) Underdrive.

Fig. 12-3. Two-tone test waveforms.

Ans. This is the frequency at which the common-base current gain is 3 db down from its 1 kc value. These figures are valuable in connection with the design of r-f amplifiers, fixed frequency oscillators, mixers, variable frequency oscillators, and self-oscillating mixers.

16. What is inductive and capacitive reactance? How are their phase angles related?

Ans. A measure of the combined effects of capacitive and inductance on an alternating current. The effect is dependent on frequency and results in a phase difference between current and voltage. While the phase angle in both types of reactance is 90 degrees, in an inductive reactance the voltage leads the current by 90 degrees and, in capacitive reactance, the voltage lags the current by 90 degrees.

17. How does the positioning of a powdered iron tuning slug affect the frequency of the oscillator it is tuning?

Ans. Insertion of a powdered iron slug within an inductance increases the inductance therefore lowering the frequency.

18. Define the deviation ratio in a frequency-modulated signal.

$$\text{Deviation Ratio} = \frac{\text{Maximum Permissible Deviation}}{\text{Highest Modulating Frequency}}$$

19. What type of signal will be produced when the output of a reactance modulator is coupled to a Hartley oscillator and multiplied in frequency?

Ans. A frequency modulated (f-m) signal will be produced. If multiplied in frequency the frequency deviation will also be multiplied to the same degree.

20. How would the reception of a single sideband signal be affected if the carrier is not completely suppressed?

Ans. Resulting heterodyne action would cause a steady tone to be received requiring more exacting receiver tuning to eliminate the unwanted transmitted carrier.

21. How does the beat frequency oscillator affect the tuning of a single sideband signal?

Ans. To properly receive a single sideband signal, the beat frequency oscillator must be set to exact zero beat with the incoming suppressed carrier modulated signal as impressed on the receiver i-f stages. Should this frequency vary, the resultant modulated signal will be distorted.

22. Can a lossy transmission line be used to transmit signals?

Ans. Yes, with lowered efficiency dependent upon degree of loss.

23. How can you distinguish between a product and an envelope detector?

Ans. An envelope detector is one which is not associated with a beat frequency oscillator and is therefore suitable only for the reception of modulated signals. Adding a bfo converts the envelope detector into a product detector suitable for the reception of continuous wave and ssb signals.

24. How can a receiver be adjusted for ssb reception when the receiver does not have a product detector?

Ans. It cannot without the addition of a beat frequency oscillator.

25. How do mica and paper dielectric bypass capacitors compare at different frequencies?

Ans. Paper dielectric capacitors while suitable at relatively low frequencies have excessive internal inductance and dielectric losses for satisfactory use at vhf. Mica dielectric capacitors, however, can be successfully used at both high and low frequencies as they have much lower internal inductance.

26. How do filter capacitors made of mica and paper compare at different frequencies?

Ans. For r-f filtering at higher frequencies, the large capacity of paper capacitors would render them useless for this purpose. However, as filter capacitors at the low commercial frequencies of power supplies, paper dielectric capacitors will prove equally as satisfactory as mica and at much lower cost.

27. Where in a receiver circuit should a limiter/blanker stage be placed to provide maximum utility?

Ans. Due to inherent characteristics of the average noise impulse, circuits of high selectivity will tend to increase the time period of the noise passed through them. It is therefore desirable to use a limiter/blanker stage ahead of circuits of high selectivity.

28. What frequency should a crystal oscillator circuit be tuned to for maximum stability?

Ans. To a point slightly to one side of the frequency of the crystal but not so far as to cause erratic oscillation. It should be on the "slow side" of the resonance curve.

29. What determines the fundamental operating range o a multivibrator?

Ans. This device produces a square waveform which shifts abruptly between two fixed values for equal lengths of time. The fundamental operating range is determined by the time constant of capacitance and resistance in the feedback circuits. Voltages and inherent characteristics of tubes and transistors in the circuit also act to affect the range.

30. What does the term "power factor" mean in reference to electric power circuits?

Ans. This is the ratio of actual power of alternating or pulsating current to apparent power and is found by comparing a wattmeter reading to voltmeter-ammeter readings.

31. What factors determine the frequency at which a quartz crystal will oscillate?

Ans. The angle at which it is cut, it's thickness, operating temperature and associated circuitry.

32. Explain the properties of a quarter-wave section of r-f transmission line.

Ans. From the amateur standpoint, the most outstanding property of a quarter wave section of r-f transmission line is its ability to act as an impedance transformer. This simply means that a load, such as presented by an antenna, of one value of impedance, can be matched to the excitation source at the input end of the line if the line is so designed as to reflect a characteristic impedance equal to the square root of the product of the two impedances. The matching section of line can be either the open wire type or those of solid dielectric such as coaxial cable. The average range of impedances dealt with in this connection in amateur applications is roughly from about 50 to 600 ohms.

33. How should a wavetrap be connected to a receiving antenna circuit to attenuate an interfering signal?

Ans. Commonly used wavetraps are of two types; series and parallel connected combinations of inductance and capacitance. A series-connected trap should be inserted in parallel with the antenna and ground connections of the receiver. A parallel-connected trap should be in series with the antenna lead to the receiver.

34. Why are synchronizing pulses transmitted with television signals?

Ans. To lock in or synchronize the scanning lines of the tv camera with the trace lines on the picture tube in the receiver.

35. How may an amateur check his transmitter for spurious sidebands?

Ans. The most common method is to use a sensitive and selective receiver with the antenna disconnected and tune through a relatively wide frequency spread with bfo turned on and transmitter in operation. Spurious sidebands will be heard as readily identifiable beat notes occurring with voice peaks.

36. How can the safe power input to a crystal oscillator circuit be determined?

Ans. Voltage and current should be in accord with the recommendations of the manufacturer. Should heating or excessive drift be evident it is a good indication that the safe power input is being exceeded.

37. How is the decibel used for voltage and power calculations?

Ans. For voltage calculation the formula db = 20 $\log_{10}$ V2/V1 is applied provided the points of measurement of both the input and output voltages are the same impedance value. To determine the power ratio on which the decibel is based, the formula db = 10 $\log_{10}$ P2/P1 is used. Fig. 9-2 gives all the decibel formulas.

38. How are transistors biased for amplifier operation? How are they biased for cutoff (open circuit) and saturation (short circuit) ?

Ans. For class-A and Class-B amplifiers a suitable forward bias must be applied. In a class-C amplifier the bias may be omitted altogether if the base is returned to the emitter through an r-f choke. If the same d-c potential exists at the base and emitter, there is no base current and the bias is said to be at cutoff. Biasing to saturation means that with increase of bias little or no increase in collector current results.

39. How do npn transistors differ from the pnp type? How does their bias differ?

Ans. The npn type consists of two layers of material rich in electrons between which is sandwiched a layer of material rich in "holes" but difficient in electrons. In the pnp type, the opposite is true; the layer rich in electrons is placed between two layers rich in holes. In an npn type a positive bias is applied to the collector and base as opposed to the emitter whereas the pnp type requires that the collector and base be negatively biased.

40. How is the output circuit of a transmitter adjusted to increase or decrease its coupling to the antenna systems?

Ans. In transmitters inductively coupled to an antenna system, the most common arrangement is to provide a means for mechanically changing the physical relationship between the final amplifier inductance and the antenna coupling inductance or link thus changing the mutual inductance of the two inductors. This is sometimes accomplished also by varying the electrical value of either or both inductances usually by taps on one or both inductors. In transmitters fitted with so-called pi output networks, decreasing the capacitance of the network output capacitor will result in an increase of coupling to the antenna system and vice-versa. With each adjustment of the output coupling capacitor, readjustment of the final amplifier tuning capacitor must also be made to maintain resonance in the tank circuit.

41. How do filters attenuate harmonic emissions?

Ans. Such filters take a number of forms. A series- or parallel-tuned trap is generally effective where only one harmonic frequency is involved. A low-pass filter can be inserted in a transmission line to absorb or suppress all frequencies above its cutoff frequency. High-pass filters are most commonly used in connection with harmonic suppression in receivers, particularly those at television frequencies.

42. List several advantages and disadvantages each for class-A, class-B, and class-C amplifier operation.

Ans. *Class A: Advantages*

a. Negligible distortion in output if properly adjusted.
b. High power amplification ratio.
c. Requires less driving power.

Class B: Advantages

a. High efficiency.
b. Good linearity.
c. Low distortion.

Class C: Advantages

a. High efficiency.
b. Well adapted to c-w transmission and to direct r-f amplification.
c. Can be driven to saturation point.

Class A: Disadvantages

a. Low efficiency.
b. Low power output.
c. Rigid adjustment requirements.

Class B: Disadvantages

a. High audio frequency distortion (unless used push-pull).
b. High driving power.
c. Varying load on driver stage.

Class C: Disadvantages

a. Low power amplification ratio.
b. Not suitable for ssb operation.
c. Nonlinear.

43. What are some different types or sources of noise voltage in reception? How is each type generated?

Ans. Often referred to as "background noise" in receivers, this is an inherent characteristic of resistance resulting from minute movement of electrons. As the degree of such movement is dependent on heat, this type of noise generation is referred to as thermal noise. A similar noise generation is produced by electron movement within a vacuum tube under normal operating conditions (shot noise). Man-made noise in a receiver is created by a variety of sources such as motor commutators producing a harsh, grating sound, electric vibrators such as shavers which produce a rapid buzzing, neon and fluorescent lights generating a buzz in step with the frequency of the supply current, and automotive and similar internal combustion engines with a rapid popping noise cycling in direct relation to the engine speed. In short any device which causes sparking upon making or breaking a contact is generally a noise source. Natural noise results from the vagaries of nature and is commonly referred to as "static." This results from various electrical disturbances in the atmosphere such as lightning. Sometimes a similar cracking and continuous sound is heard in the vicinity of machinery operating from rapidly moving belts over metal wheels or pulleys generating slight sparking at contact points between leather and metal; this is referred to as "frictional" or static electricity.

44. What are the current and voltage characteristics along a transmission line when it is matched, and when it is mismatched?

Ans. Assuming a low loss line of the matched type, both current and voltage will remain constant throughout its length. There will, however, be a slight tapering off from the input end of the line toward the load in direct ratio to the degree of the resistance or loss in the line. A mismatched line will show both current and voltage rising and falling rythmically along the line, their maximum and minimum values occurring one quarter wave apart. The voltage minimums however, will occur at current maximums and vice versa.

45. How do receivers for remote control of objects and regular types of communication receivers differ in basic operation?

Ans. Communication receivers are tunable over a wide range of frequencies and actuate speakers or headphones. Remote control receivers for control of model boats, planes, and similar devices generally are permanently set on a predetermined frequency which cannot be changed and they actuate relays or similar mechanical devices to control various functions.

46. How will a long and a short time constant agc circuit affect reception?

Ans. The time constant must be carefully calculated to produce sufficiently swift recovery of a received signal to permit satisfactory reception of c-w and ssb signals. This period, however, must not be so short as to prevent receiver gain from remaining at a uniform level between the c-w code characters or short conversational gaps. In a-m reception the modulation must be filtered entirely from the agc rectifier but the time constant should be short enough to permit the agc to follow rapid signal variations.

47. What useful functions does a balanced modulator perform in a radio transmitter?

Ans. Carrier elimination or attenuation is one function of the balanced modulator. Likewise it can be so adjusted to permit passage of a selected amount of carrier to pass to the modulator output with the sidebands.

48. How does the directivity of an unterminated "V" antenna and parasitic beam compare?

Ans. A parasitic beam antenna has its major lobe radiating in a unidirectional pattern whereas the "V" antenna radiates bidirectionally on a line intersecting the V.

49. If a crystal lattice bandpass filter has bandwidths of 1.5 Kc at the 6 db points and 3 Kc at the 60 db points, calculate the shape factor.

Ans. The ratio of the bandwidth at 60 db down, to the bandwidth at 6 db down represents the shape factor. In this hypothetical case, the shape factor would be 2:1.

50. What would happen if the grid-bias supply of a class-C modulated amplifier were suddenly short circuited?

Ans. The plate current would soar to a dangerously high value with possible damage to tubes and other components. Output would cease entirely or be greatly reduced and the modulation would no longer be linear.

51. How do trimmer and padding capacitors affect receiver tuning?

Ans. Trimmers are capacitors capable of being adjusted to vary the frequency of an l/c circuit over a small segment. Their most popular application in amateur radio receivers is for the purpose of band-spreading. Padders serve a somewhat similar purpose although more generally used in connection with padding a variable capacitor to permit small increase in its overall capacity.

52. What is the phase relation between the input and output signals in the common-emitter, common-base, and common-collector transistor circuits?

Ans. The input and output signals in the common-base and common-collector circuits are in phase, whereas in the common-emitter circuit, the output signal is 180 degrees out of phase with the input signal.

53. How can a transmitter be tested for self oscillation? What precautions should be observed during testing?

Ans. The oscillator stage of the transmitter should be disabled. Lacking this normal source of excitation, tube voltages and currents should be observed in all succeeding stages under key down conditions and if found to exceed the manufacturer's specified safe dissipation, grid bias should be increased to bring the dissipation within the prescribed limits. An absorption wavemeter, field strength meter, or other device by which r-f radiation can be detected, is then coupled to the various normal radiating circuits of the transmitter. Self-oscillation and the magnitude will appear as an indication on the exploring device. If sufficient metering flexibility is available in the transmitter, an indication of grid current in any stage would indicate self oscillation. These exploratory tests should be made while adjusting the tuning variables of each stage throughout their normal range. Plate current indications should also be checked and should not vary during tuning processes if self oscillation is nonexistent. Inasmuch as such tests involve proximity to dangerous voltages, the usual safety precautions should be taken to avoid shock hazards.

54. How can unwanted vhf resonance in a transmitter amplifier be moved from television channel frequencies?

Ans. This condition can almost invariably be due to resonance in circuits with the tv channel experiencing the disturbance. It is necessary to upset such resonance by altering lengths of various leads within the transmitter, pruning major inductances and possibly replacing bypass capacitors with some of different value as well as r-f chokes, to shift the resonant frequency away from the affected television channel.

55. A 70-ohm transmission line is connected to a 35-ohm antenna. Calculate the standing wave ratio (swr), the reflection coefficient, and the percent reflected power. If 10 amperes are flowing in the antenna terminals, what is the current in a transmission line node?

Ans. Dividing the largest impedance (70 ohms) by the smaller (35 ohms) results in a standing wave ratio of 2:1. The reflection coefficient is a term used to express the amount of current or voltage reflected back to the input of the line from the load, in percentage. This is determined by the formula:

$$\mathrm{k} = \frac{\mathrm{SWR} - 1}{\mathrm{SWR} + 1} = \tfrac{1}{3} \text{ or } 33\tfrac{1}{3}\%, \text{ in the foregoing instance.}$$

Since the reflected power is proportional to the square of the reflection coefficient, the reflected power would therefore be 11.1% in the example. With a standing wave ratio of 2:1, the current will be 5 amperes at a node.

56. What is a grid-bias modulated amplifier? Should the fixed bias have a high or low internal resistance?

Ans. An audio voltage is added in series with the bias supply of the modulated amplifier. Since the bias voltage can control the output of the power amplifier, variations of the bias voltage can produce amplitude modulation (a-m) of the output. When the bias and modulating signal values are adjusted so that the grid will not draw current at any time during modulation, then the modulator tube is working into practically an infinite ohm load resistance, and almost no power is required to produce modulation; therefore a high internal resistance source can be used.

57. Of what importance is the signal-to-noise ratio of a receiver? At what radio frequencies is this ratio most important?

Ans. The signal-to-noise ratio in a receiver is the relationship of the strength of an incoming signal to the strength of the noise which accompanies it. The degree of ability to detect a signal through such noise determines the ratio. Natural static and man-made noise are taken into consideration and the inherent receiver noise is disregarded. The ratio is of greatest importance on the vhf and uhf frequencies where reception is particularly susceptible to noise.

58. What are aurora-reflected vhf signals? If such a signal is heard, what does it sound like?

Ans. A wavery signal of coarse pitch. It is generally associated with propagation reflected from atmospheric sources from which light phenomenon is visible as aurora borealis in the north polar region and aurora australis in the southern polar area.

59. Define the conversion efficiency of a mixer tube.

Ans. The ratio of i-f plate circuit output voltage to r-f signal voltage appearing on the grid is known as conversion efficiency.

60. How does a cathode-ray tube operate? How should the plates of a cathode-ray tube be biased?

Ans. A cathode-ray tube is a vacuum tube in which a beam of electrons is focused on a phosphor screen, which glows wherever the beam strikes it. The beam is deflected electronically and its intensity varied by the signals applied to the tube. Thus a visual display of the signal is produced on the screen. Biasing of the plates should be such as to locate the visual pattern in the desired position.

61. What are some causes of the excessive production of harmonics in r-f amplifiers? How can these causes be remedied?

Ans. Harmonics can result from a variety of causes among which are (1) circuit maladjustment, (2) excessive drive from preceding stages, (3) unshielded components and circuitry, (4) unshielded external power wiring, (5) unshielded enclosure for transmitter, (6) the lack of low-pass filter in the antenna feed line; and (7) improper bias voltages.

62. What effect does an untuned antenna and transmission line have on a transmitter?

Ans. An untuned radiating system will prevent proper loading of the transmitter output circuit unless the transmitter itself has a suitable output network capable of variation over a wide range of impedance values. The efficiency of the entire radiating system will be appreciably lowered and a high standing-wave ration will apper on the transmission line.

63. How are reactance tubes used?

Ans. Reactance tubes are so connected in an r-f oscillator circuit as to simulate variable capacitance or inductance. Variations in the amplitude of a voice signal with corresponding variations in plate current are followed in voice frequency through the reactance tube thereby causing a deviation frequency shift in the oscillator circuit for f-m operation. If used in the amplifier stage of a transmitter to vary the tank tuning, phase modulation is then possible.

64. How are phasing capacitors used in crystal filters?

Ans. Using phasing capacitors in a crystal filter serves to shift the parallel-resonant frequency of the crystal thereby permitting an undesired signal to be greatly attenuated or eliminated by providing what is commonly referred to as a "rejection notch."

65. What means may be employed to measure low frequencies? High frequencies? Vhf and uhf?

Ans. Audio frequencies may be measured by means of an accurately calibrated audio-frequency oscillator. High- and low-radio frequencies can be measured by an accurate heterodyne frequency meter or with an absorption type wavemeter also of a high degree of accuracy. The lower vhf frequencies can often be measured with a similar device but at higher frequencies including the vhf range, the somewhat less accurate but relatively satisfactory Lecher wire arrangement, which is a linear variation of the absorption frequency meter, may be used.

66. How are grounded-grid amplifiers used in electronic circuits? List some advantages and disadvantages of their use.

Ans. Grounded-grid amplifiers in effect reverse the conventional grid input-grounded cathode arrangement in that the input is applied at the cathode and the grid is at ground potential as far as a-c is concerned. The output is then taken between the plate and ground. A grounded-grid amplifier has higher output by reason of additive drive from previous stages being carried through to the output. An additional advantage is in allowing a relatively constant load on the driver stages when a grounded-grid amplifier is employed in ssb applications. In receiver applications, the grounded-grid permits use of triode tubes with little or no neutralization requirement. In some applications, such as c-w, radioteletype, and f-m operation, greater driving power is required for a grounded-grid amplifier operating as class-C.

67. What constitutes a parasitic antenna element?

Ans. Such an element is one with no physical connection to a transmitter but which receives power from a driven element through electromagnetic coupling. Parasitic elements are placed parallel to and in the r-f field of a driven element and resemble the driven element physically. Adjustment of the parasitic element is usually made by lengthening or shortening.

68. What is the image response of a receiver? How can it be reduced?

Ans. In a superheterodyne receiver which uses intermediate frequency stages, the upper and lower sidebands of an incoming signal are converted to a predetermined frequency in the intermediate stages thereby presenting a new frequency more adaptable to amplification. However, the sideband frequencies will also appear in the passage of the signal through the various stages. Only one of these frequencies is chosen for reception and the other (unused) one is the image frequency. As this represents an unwanted signal, attenuation is secured by using a frequency as high as possible for the intermediate frequency and by making all circuits as selective as possible.

69. What is a third-party agreement? What countries have agreements with the United States?

Ans. See question 21, Chapter 11.

70. What effect will extending the low-frequency response to a signal have on the design of a ssb receiver?

Ans. The low frequency response will be attenuated to a degree commensurate with the amount of frequency shift.

71. List some different types of beam antennas.

Ans. (1) *Broadside arrays*, which may be either bidirectional (single array) or unidirectional (using a second array associated with the first).

(2) *Parasitic arrays*, wherein a series of elements with no electrical connection to the transmission line, receives and reradiates r-f energy received through electromagnetic coupling to a similar series of driven elements. Parasitic arrays are essentially unidirectional.

(3) *End-fire arrays* which accomplish radiation in the direction desired by proper phasing.

(4) *Rhombic and "V" beams;* these are of the long-wire types and may be made either undirectional or bidirectional.

(5) *Loop antennas;* most widely used in a form known as the cubical quad, these consist of two identical loops one of which is a driven element and the other, a parasitic element, electromagnetically coupled to the first.

72. What radiotelephone transmitter operating deficiencies may be indicated by a decreasing antenna r-f current during modulation of the final r-f amplifier?

Ans. Improper adjustment of the final r-f amplifier; insufficient output from the modulator stage; insufficient drive; poor voltage regulation; improper plate and/or bias voltages; over-coupling of final tank.

73. What improper operating conditions are indicated by the upward or downward fluctuations of a class-A amplifier plate current when a signal voltage is applied to the grid?

Ans. Improper grid bias. Downward deflection would indicate that the negative bias was inadequate; a deflection upward would indicate excessive grid bias. Excessive drive could also be responsible and should be checked and corrected if found to exist.

74. What improper operating condition is indicated by grid current flow in a class-A amplifier?

Ans. This is an indication of excessive grid drive.

75. What may be the cause of a decrease in antenna current during modulation of a class-B r-f amplifier?

Ans. Poor linearity; Class-B amplifiers should not be modulated but used only as a linear amplifier.

76. What determines the skip distance of radio waves?

Ans. The combined relations of frequency, time of day, and atmospheric (ionospheric) conditions.

77. How can parasitic oscillations be prevented?

Ans. See Question 12, Chapter 11.

78. Give some proven methods of harmonic reductions in transmitters.

Ans. See Question 5 in Chapter 11.

79. Describe briefly some well-known types of antennas and antenna systems used by amateurs which do, and do not, reduce harmonic radiation.

Ans. Any antenna fed directly from a transmitter, with a transmission line which represents a bad mismatch at the load (antenna) end will be rich in harmonics. Compensation for such mismatch through suitable antenna matching devices or tuners can be made within reasonable limits. Many amateur transmitters have integral combination output and antenna matching networks which permit the output to be matched to loads within a relatively wide range. Such networks provide a sufficiently close impedance match between transmitter and antenna to greatly attenuate harmonics. Lacking this facility, l/c coupling and matching units are inserted into the transmission line externally at the input end and serve the same purpose. Random-length wire antennas fed at random points are particularly bad harmonic generators unless proper impedance matching from transmitter to load (antenna) is added. However, such harmonics can be greatly attenuated or eliminated through use and proper adjustment of suitable coupling devices. The half-wave dipole—either end or center fed—produces minimum or no harmonic radiations when the load is properly matched to the line. This matching can be by integral transmitter output networks or similar external matching devices.

CHAPTER 13

Miscellaneous Information

13-1 In your study for the Advanced- and Extra-class license examination, there remain a number of miscellaneous items which, while not in themselves requiring full chapter treatment, should be recognized. A few questions will doubtless appear in connection with such subjects, and an attempt will be made to anticipate them by brief explanatory paragraphs. Foremost perhaps in this category is the familiar vacuum tube, often and rightly referred to as the "heart of radiocommunication."

13-2 Much has been written—even complete manuals devoted exclusively to the subject of vacuum tubes—but such complete treatment for purposes of the license examination would be superfluous in a handbook of this kind. As licensed amateurs of at least two years' experience which you are required to have to be eligible for the Extra-class examination, vacuum tubes in general should be as familiar to you as a coffee percolator or soldering iron. While hundreds of types of such tubes are manufactured by a varity of applications, as an amateur you will be concerned with relatively few. The average *receiving* tubes which you use are of rather minor importance from the examination standpoint. The knowledge of them which you already have, should suffice to see you through the occasional question which may appear in your examination. The FCC is much more interested in your knowledge of *transmitting* tubes and related equipment, all of which are capable of interfering with other radiocommunications.

This is particularly true where, because of inexperience perhaps, maladjustments have been made which aggravate this condition. The FCC therefore wants to know, by actual examination, the extent of your knowledge of vacuum tubes and circuits, as well as items of equipment with which they are combined. However, the *basic* tubes with which you are concerned in amateur practice fall into but four categories: the diode, triode, tetrode, and pentode.

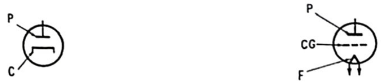
13-3 Diodes contain only two elements: a plate and a cathode (or filament). They are used almost exclusively in rectifier applications. Some may have small mercury pools confined within the base of their envelope. These, of course, are the familiar mercury-vapor tubes discussed in Chapter 3. Others may be of the highly exhausted vacuum type. While either type may contain *two* plates and a cathode or filament and may appear at first thought to be in the triode class, actually they belong in the diode family since, in rectifier circuits, *both* plates ordinarily do not operate simultaneously. Because they alternate, their effective operation is as a diode.

13-4 A triode has *three* elements, or electrodes as they are sometimes called. The third element consists of a wire grid inserted between the cathode and the plate. (No further reference to the "filament" will be made; only the term "cathode" will be used, since both perform identical functions as the heated electrode of the tube.) The single grid in a triode is known as the *control grid,* because its function is to control the plate current with relation to the excitation supplied it from any associated circuit configuration.

13-5 A tetrode tube contains an additional grid known as a "screen grid." This extra grid serves to balance out the interelectrode capacitance of the tube, thus reducing such internal capacitance to practically zero and making neutralization unnecessary in most cases.

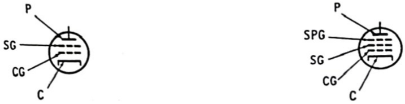
13-6 By the insertion of still another grid between the screen grid and the plate, a five-element tube is created, known as a pentode. This third grid, identified as the *suppressor grid,* functions as a shield against secondary emission between the screen grid and the plate. Secondary emission is the name given to electrons attracted to the positively charged screen grid after bouncing off the plate and attempting to wander at random within the tube envelope. The suppressor grid prevents these wandering electrons from being attracted to the screen grid; thus they return to the plate, where they can do no harm.

13-7 With the preceding simple definitions and your knowledge of vacuum-tube theory and where, how, and why each particular tube can be used in radio and associated power circuits, you have about all that you will need to know in connection with vacuum tubes. Obviously, you would not use a diode tube as a radio-frequency detector, although it will work in this manner, but not much more effectively than the crystal detector of pioneer radio broadcast days. Neither would you put a pentode to work in a power-supply rectifier system. You should, however, be able to immediately recognize the symbols adopted for each of these types of tubes and to call them by name as soon as you see them. Fig. 13-1 will clarify this for you if you have become a bit hazy in this particular.



(A) Diode (two elements).

(B) Triode (three elements).



(C) Tetrode (four elements).

(D) Pentode (five elements).

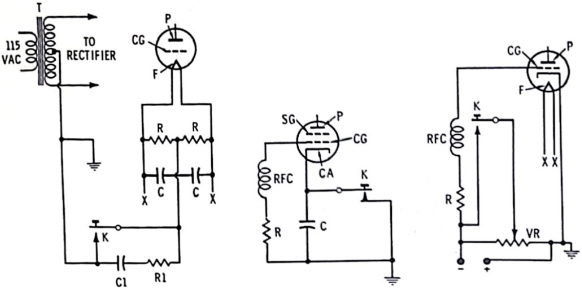
KEY TO SYMBOLS
C - CATHODE
CG - CONTROL GRID
SG - SCREEN GRID
SPG- SUPPRESSOR GRID
F - FILAMENT
P - PLATE

Fig. 13-1. Vacuum-tube types.

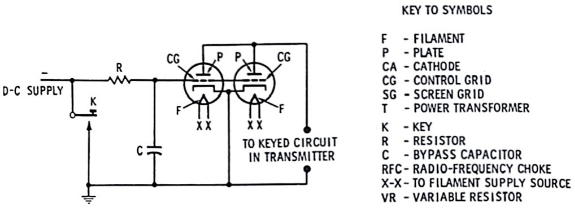
13-8 Another item which can be classified as "miscellaneous" is the *keying* of an amateur transmitter. Keying refers to either the manipulation of a telegraph key as in c-w code transmission or the turning on and off of a radiotelephone transmitter. In either mode of transmission, keying can be accomplished at a number of points in the circuit. Actually, a telegraph key of any type is nothing more than a switch mechanically designed so that it can be conveniently and rapidly manipulated by hand; the rapidity is determined by the desired speed of transmission. Such keys are of various types. Almost everyone has seen a so-called *hand key* in telegraph offices and on the telegraph table in railway stations. Manipulation of this type is completely by hand movements. An improvement in the mechanical structure of a key was made many years ago and finds wide acceptance in commercial telegraph and radio circuits as well as by amateurs. This is the semiautomatic type of key, casually referred to by telegraphers as a *bug*. It automatically forms the correct number of dots required in a telegraph code character when its "paddle," or handle, is actuated by the hand of an experienced operator. He need only insert the dashes at the proper point by manual manipulation. A so-called *fully-automatic* type was later developed, and it too is widely used in both commercial and amateur practice. It picks up where the bug leaves off; in addition to making the dots as the bug does, it also automatically makes the required number of dashes, which is determined by the operator's manipulation of the paddle. Such keys are not really fully automatic, although the terms serve to identify them adequately. Human manipulation by the operator's fingers is necessary with both the semiautomatic and the fully automatic types, just as with the hand key.

13-9 Regardless of where or how telegraph keying is accomplished in the transmitter circuits, basically it must start with manual manipulation by a skilled operator. From there it may key the transmitter circuits directly or it may pass through a *keyer tube* to accomplish this. The output of the keyer tube merely performs the circuit functions of the manually operated key. In a conventional vacuum-tube keyer, the keyer tube has its plate and cathode connected in the circuit wherein keying is to take place. The grid of the keyer tube is biased to cutoff so that no plate current flows. The manually operated key is so connected that, by closing it, the bias on the keyer tube is decreased to the point where full plate current will flow, thus allowing the tube to conduct.

Actual keying of the transmitter can take place at many points in the circuit; we have *center-tap* keying, *cathode* keying, *blocked-grid* keying, and a variety of others. Such keying may take place in the oscillator or amplifier stage; sometimes it is arranged to occur simultaneously in both. Another keying arrangement keys both the screen grid of the driver stage and the final r-f amplifier. The subject of keying embraces many schools of thought and is treated in rather great detail in various manuals and handbooks. Fig. 13-2 shows a number



(A) Center-tap keying. (B) Cathode keying. (C) Blocked-grid keying.



KEY TO SYMBOLS

F - FILAMENT
P - PLATE
CA - CATHODE
CG - CONTROL GRID
SG - SCREEN GRID
T - POWER TRANSFORMER
K - KEY
R - RESISTOR
C - BYPASS CAPACITOR
RFC - RADIO-FREQUENCY CHOKE
X-X - TO FILAMENT SUPPLY SOURCE
VR - VARIABLE RESISTOR

(D) Vacuum-tube keyer.

Fig. 13-2. Basic keying circuits.

of basic keying circuits which should enable you to satisfactorily answer any questions pertaining to this.

While keying has been discussed mainly from the radiotelegraph standpoint, the same applies to radiotelephone operation. In the latter the key is more in the nature of a switch which remains closed during transmission and open when receiving. Like the telegraph key, it merely serves to turn the r-f carrier on or off as may be required, but not of course by rapid manipulation as in telegraphy.

13-10 Another subject deserving consideration under the heading of "miscellaneous" is the U. S. Radio Laws and the Regulations of the Federal Communications Commission. This is represented by Element 3 of the Extra-class license examination. Inasmuch as this same element is also a requirement of the General- and Advanced-classes of license, you should be rather familiar with the "radio rules of the road." If you are a bit hazy on some points, you can find the complete text of applicable laws and regulations in the various license manuals published for these classes.

13-11 The subject of *operating procedure* could be dealt with in this chapter, but actually this is irrelevant, and little if anything will appear in this connection in your examination. It is, however, very possible that you will receive several questions pertaining to the "Q" signal, such as "QRT—Stop sending," "QRX?—Shall I stand by?", etc. As an experienced operator you are, or should be, completely familiar with the use and meaning of all of these which are pertinent to amateur radio operation. There is, however, one little catch here which you may easily overlook in answering a question. Just remember that if the "Q" signal is followed by a question mark, it *is* a question; if *no* question mark follows it, it is a reply, or a statement. For example, were you to be asked to define the signal "QRS?", you would state it in this manner: "Shall I send slower?" Had the question asked you to define the signal "QRS," your answer should be "Send slower"; just a simple little question mark changes the meaning—watch for it.

11-12 Radio teletype, remote control of objects by radio, and indulgence in stratospheric radio experimental work could all be treated here since an occasional question appears in respect to one or more of these. If you have been engaging in such activities, you will find no difficulty in arriving at a correct answer. If your interests have not developed along these lines, take a little time to look up these subjects in the specialized handbooks dealing with them; there are a few paragraphs devoted to such specialized applications of ham radio in most of the general-type handbooks and manuals. This information should be sufficient to carry you over this minor hurdle. In other words, whichever of the many facets of ham radio you have more or less ignored through lack of interest in their pursuit, look up and gain a bit of knowledge of their basic theory.

APPENDIX A

Examination Elements

All FCC amateur radio license examinations are divided into "elements." The FCC Rules and Regulations pertaining to the various classes of amateur licenses and the requirements for each follow:

OPERATOR LICENSE EXAMINATIONS

§ **97.19 When examination is required.**

Examination is required for the issuance of a new amateur operator license, and for a change in class of operating privileges. Credit may be given, however, for certain elements of examination as provided in § 97.25.

§ **97.21 Examination elements.**

Examinations for amateur operator privileges will comprise one or more of the following examination elements:

(a) Element 1 (A): Beginner's code test at five (5) words per minute;

(b) Element 1 (B): General code test at thirteen (13) words per minute;

(c) Element 1(C): Expert's code test at twenty (20) words per minute;

(d) Element 2: Basic law comprising rules and regulations essential to beginners' operation, including sufficient elementary radio theory for the understanding of those rules;

(e) Element 3: General amateur practice and regulations involving radio operation and apparatus and provisions of treaties, statutes, and rules affecting amateur stations and operators;

(f) Element 4(A): Intermediate amateur practice involving intermediate level radio theory and operation as applicable to modern amateur techniques, including, but not limited to, radiotelephony and radiotelegraphy;

(g) Element 4(B): Advanced amateur practice involving advanced radio theory and operation as applicable to modern amateur techniques, including, but not limited to, radiotelephony, radiotelegraphy, and transmissions of energy for measurements and observations applied to propagation, for the radio control of remote objects and for similar experimental purposes.

§ 97.23 Examination requirements.

Applicants for original licenses will be required to pass the following examination elements:

(a) Amateur Extra Class: Elements 1 (C), 3, 4 (A), and 4 (B);
(b) Advanced Class: Elements 1 (B), 3, and 4 (A);
(c) General Class and Conditional Class: Elements 1 (B) and 3;
(d) Technician Class: Elements 1 (A) and 3;
(e) Novice Class: Elements 1 (A) and 2.

§ 97.25 Examination credit.

(a) An applicant for a higher class of amateur operator license who holds a valid amateur operator license issued upon the basis of an examination by the Commission will be required to pass only those elements of the higher class examination that were not included in the examination for the amateur license held when such application was filed. However, credit will not be allowed for licenses issued on the basis of an examination given under the provisions of § 97.29 (b).

(b) An applicant for any class of amateur operator license, except the Extra Class, will be given credit for the telegraph code element if within five years prior to the receipt of his application by the Commission he held a commercial radiotelegraph operator license or permit issued by the Federal Communications Commission.

(c) An applicant for the Amateur Extra Class operator license will be given credit for examination elements 1 (C), 4 (A), and 4 (B), if he so requests and submits evidence of having held a valid amateur radio station or operator license issued by any agency of the U.S. Government during or prior to April 1917, and qualifies for or currently holds a valid amateur operator license of the General or Advanced Class.

(d) No examination credit, except as herein provided, shall be allowed on the basis of holding or having held any amateur or commercial operator license.

APPENDIX B

Recommended Supplemental Material

The following list of publications represents recommended reading and study to supplement the material contained in this handbook. The name and address of the publisher appear below each group:

Title	**Price**
The Radio Amateur's Handbook	$ 7.00
The ARRL Antenna Book	2.00
The American Radio Relay League, Inc., Newington, Connecticut 06111	
CQ Amateur Radio License Guide	2.50
Cowan Publishing Corporation, 14 Vanderventer Ave., Pt. Washington, L. I., N. Y. 11050	
Amateur Radio Theory Course	3.95
Ameco, Division of Aerotron, Inc. P. O. Box 6527, Raleigh, N. C. 27608	
ABC's of Transistors	2.25
Howard W. Sams & Co., Inc., Indianapolis, Ind. 46206	
Single Sideband: Theory & Practice	6.95
Radio Handbook	12.95
Editors and Engineers, Ltd., P. O. Box 68003, New Augusta, Indiana 46265	

It is recommended that you procure as many of these publications as you feel that you can; each contains a wealth of information.

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advanced and extra-class amateur license handbook

by Howard S. Pyle, W7OE

The introduction of the incentive license program by the FCC and the restoration of the Advanced-Class license have added new emphasis to the higher classes of amateur radio licenses. Where formerly the General-Class licensee received all privileges, now the privileges increase with each grade of license. Thus, there is added incentive for each amateur to work toward the highest grade obtainable—the Amateur Extra-Class License.

For those who have not held a "ticket" for the required 2 years and those who may not have the technical knowledge, or 20-word-per-minute coded sending and receiving ability, the Advanced-Class license offers a convenient stepping stone on the way up.

This book introduces the reader to the types of material on which the Advanced & Extra-Class license examinations are based. It not only provides most of the additional information needed by the General-Class licensee, but also includes a large part of the basic theory needed by all classes of license holders.

The author first explains the requirements for the various licenses, then describes proven methods of increasing code speed to the level required for the Extra-Class license. Chapters are then devoted to the various subjects such as oscillators, multipliers, modulation, and radiating systems. Throughout these chapters questions of the type used on the FCC examination are included. Two chapters include the answers to all the sample study questions that the FCC has released for the Advanced and the Extra-Class license exam.

Advanced & Extra-Class Amateur License Handbook is a complete one-volume study guide for obtaining these licenses. In addition it will serve as a handy reference guide for all amateurs.

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Howard S. Pyle has been a ham for 60 years, starting as a lad in 1908. He has served as an assistant U.S. radio inspector and as an electronics engineer with the U.S. Government. He is a senior member of the IEEE and past vice-director of the Northwestern Division of the ARRL. Now "retired" he frequently contributes to the various amateur radio publications, writes books, and still finds time to spend in his "shack" at Mercer Island, Washington, where his W7OE is a familiar call to fellow hams. His other popular SAMS books include: *ABC's of Ham Radio* (a study guide for the novice class license), *General-Class Amateur License Handbook* (a study guide for the Technician, Conditional, and General-Class licenses), and *Building Your Amateur Radio Novice Station*.

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